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[THIRD SERIES.]

ART. LIV.—*Geological relations of the Limestone Belts of Westchester County, New York;* by JAMES D. DANA. With a map (Plate XIX).*

4. *Southern Westchester County and Northern New York Island.*

IN the account, on former pages of this memoir,† of Southern Westchester County and the adjoining part of New York or Manhattan Island, many facts of general interest were omitted. The developments which have been announced have given the region great geological importance, since they prove, on evidence both stratigraphical and paleontological, that the limestones, gneisses and mica schists are part of the long north-and-south line of the Green Mountain formations, and also part of the Lower Silurian series which spread westward over the continent.‡ I propose here to describe, more fully than has been done, the positions and relations of the limestone areas, and the flexures in these and the adjoining rocks. Toward this end

* For the earlier parts of this memoir, see pages 21, 194, 359 and 450 of the last volume.

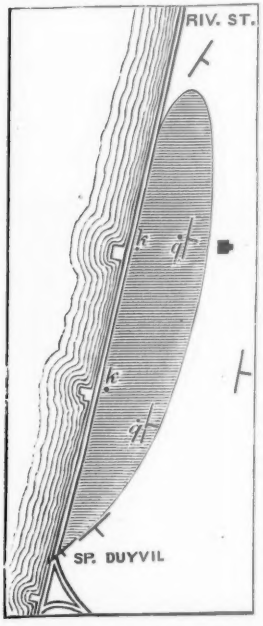
† Vol. xx, p. 360.

‡ The limestone of the Green Mountain region, as has been pointed out, includes the limestones of the successive periods from the Calciferous, and probably Primordial, to the Trenton period, as proved by the occurrence of Calciferous, Quebec and Trenton fossils in the beds of the same continuous limestone formation, both to the north, in Vermont, and to the south in Dutchess County, New York. In this they resemble the Lower Silurian of much of the Mississippi basin, while in contrast with that of Central and Eastern New York. The limestones of the continental interior lie to the west of the Appalachian Mountain region, and those of the Green Mountains have their largest development in Vermont to the west of the chief line of the Green Mountains.

I have made many additional observations which are here included. The facts will be found to explain the origin of some of the features of New York Island, and indeed of New York City, while illustrating also certain general stratigraphical features of the Green Mountain system. In order that the points may be readily understood, a large geological map of the area is here added. (See Plate XIX.)

Explanations of the Map.—The accompanying map is drawn on a scale of one mile to two inches. For the sake of precision in locating observations, it has upon it the streets that have been laid out over the surface.* I have added also, from early

* This map has been copied, by permission, from one of the maps (Nos. 14, 15) of the excellent quarto Atlas of Westchester County, published by Messrs. J. B. Beers & Co., of New York. The original map of the Atlas is a third larger in scale, and gives, among its many details, the boundaries of properties, names of owners and acreage, over the less settled portion, and many other particulars of public interest. The part of New York Island north of Central Park, or of 110th Street, is about six and a quarter miles long out of the total thirteen and a half. But it contains less than one-third the whole area of the island, and but a small part of the population of the city. I here describe, by way of



Supplement to the Article in the Number for November last, a limestone area not included in the Westchester County map of that article. It extends (see the annexed figure, and, for the south extremity of the area, the northwest corner of the accompanying map, in both of which 2 inches = 1 mile) from Spuyten Duyvil, on the Hudson, nearly to the Riverdale Station (Riv. St.). The exact outline is not determinable; for there are no outcrops on the coast owing to the stratified drift; and at Spuyten Duyvil, which is made the southern extremity, the rocks at the most northern spot (abreast of the forking of the railroad and nearly on a level with the track) is micaceous gneiss containing some layers which become crumbling from weathering and apparently because filtrating waters easily remove calcium carbonate. Similar gneiss, containing thin calciferous layers, outcrops 250 yards to the northeast, and has the same strike (N. 47° E.) and dip (70°–60° E.), as if a continuation of the eastern border of the area. Farther north, there are outcrops of the limestone, and at *q*, *q*, quarries, the more northern one on the Delafield estate. At *k*, *k* are limekilns, and the masses of limestone about the more southern appear to be partly in place. To the north of the northern quarry the eastern limit probably follows the base of a high and abrupt declivity. About the northern termination of the area, outcrops of schist occur near the river south of the Riverdale Station as well as to the north and east. The limestone at and near the quarries and the schist outside of the area to the eastward have a strike of N. 10°–18° E.; but north of the area the strike of the schist changes to N. 34° E. The schist adjoining the area is largely hornblendic. Some of the beds of limestone at both quarries contain tremolite.

maps, some details as to the original topography of New York Island, which street grading has mostly or wholly obliterated, namely: the bay and stream at the north end of the Eighth Avenue Valley, whose waters flowed northward into Harlem River; and the stream of Manhattanville Valley—a remarkable depression that crosses the island, obliquely to the bedding of the rocks, from Manhattanville on the Hudson, southeast-by-east, to East River, passing over the northeast corner of Central Park, where the park has one of its ponds and a tributary brook.

The areas on the map that are colored blue are those of the limestone, the rest being occupied by schists (mica schist and gneiss); and the dotted lines which are in continuation of the belts indicate the course of the valley, along which the limestone may perhaps extend.

The T-shaped symbols, as already explained, show, by the direction of the top of the T, the direction or strike of the bedding of the limestone and schists, and by the length and direction of the stem, the amount and direction of the pitch or dip of the beds. For the convenience of the reader, I repeat the ratios *between the stem of the* T *and half its top* which are adopted to express the angles of dip.*

Dip of 80°	a ratio of 1 : 4	Dip of 35°	a ratio of 5 : 4
70°	1½ : 4	25°	6 : 4
60°	2 : 4	20°	7 : 4
50°	3 : 4	15°	8 : 4
45°	4 : 4	10°	9 : 4

Dip of 5° a ratio of 10 : 4

A circle (fig. 21) indicates horizontality. When the dip varies greatly within very short distances, two stems are used, giving the extremes (fig. 22). If there are dips in opposite directions, stems are put on both sides of the top of the T

21. 22. 23. 24. 25.

(figs. 23, 24). These dips in opposite directions have two causes: *One* is a slight shifting to one side or the other of a vertical, of the axial plane of the fold; fig. 23 for example, indicates a variation from 70° W. to 80° E. The *other* is a consequence of local flexures or undulations in the stratification; as in fig. 24 (the dips indicated by which are 25° and 45°). And when such local flexures arch over, the symbol used, besides having stems in opposite directions, has a small circle at the center (the top of an arch or undulation being approximately horizontal), as in fig. 25.

* On a large manuscript map, a convenient length for the top of the T is eight millimeters; and this adopted, the above ratios are in millimeters. Or, if the top is made one-third of an inch long (about eight and one-half millimeters), the ratios are in twenty-fourths of an inch.

Additional notes on the Rocks.—The *crystalline schists* of the region, as I have stated, are mainly micaceous gneiss and coarse mica schist, the one graduating into the other; are generally garnetiferous, and in some places hornblendic, or contain hornblende schist in intercalated beds; and have been found to contain cyanite at localities between 4th and 5th Avenues and 42d and 51st Streets.* I have now to report that the schist is crowded with minute needles of fibrolite at several points between the same avenues farther to the north (north of 115th street), and also in Westchester County, north of Mott Haven, near the Mott Avenue bridge over the Hudson River railroad track: a fact which adds to the close relations between the rocks of New York and those of eastern Westchester County, at New Rochelle, and also those of the northern part of the county, south of Peekskill.†

Gneiss of the normal type—that is, containing only a moderate proportion of mica—is not common. A fine-grained, thick-bedded, light gray gneiss containing little black and white mica, makes the bluff bounding on the west the limestone area between Tremont and Morrisania, and has been quarried at several points. By microscopic examination of a thin slice, I have found it to be two-thirds granular quartz, so that it is in reality quartzytic gneiss or gneissic quartzyte. The other ingredients are orthoclase and microcline, with traces of black tourmaline. It is porous, and weathers rather deeply, and loses thus its black mica before it does its firmness. Among the thicker beds occurs an occasional thin layer of mica schist.

The presence of hornblende or hornblendic schist appears to have often determined a crowd of subordinate flexures and contortions in the beds, and a loss of distinctness in the minor layers. I have explained this on the ground that hornblende is relatively a fusible mineral (being of the grade 3, on von Kobell's scale of fusibility), while the feldspar (of which orthoclase is the prevailing one) and the mica (black and white) are of difficult fusibility (5 to 6, on the same scale); and, in consequence, beds that become hornblendic in the metamorphic process easily soften and bend. A good example is seen in a section on 110th Street, between 9th and 10th Avenues, where the micaceous gneiss has high dip (mostly 80° to 90°, but varying locally) and in some parts contains much hornblende. This street (the 110th) here cuts through the schist transversely to its bedding, and has on the north side a vertical face of an

* Cyanite was first found on New York Island by Mr. Issachar Cozzens, as reported by Dr. Torrey in this Journal, vi, 364 (1823); and Mr. Cozzens, in his "Geological History of Manhattan or New York Island" (1843), mentions the neighborhood of the Deaf and Dumb Asylum (which was then situated between 49th and 50th Streets and 4th and 5th Avenues) as the locality.

† This Journal, xx, 24, 200, 206.

extensive joint or fracture. The surface over a large area looks as if made up of the flat ends of great and nearly horizontal columns (fig. 26). The rock is here largely hornblendic,

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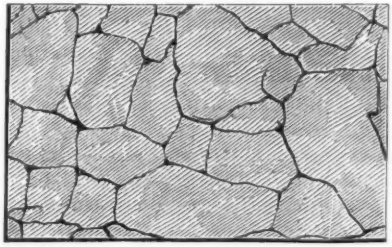

27.

and the columns are obscure in their interior bedding; but through the weathering or rusting of the flat end, the fact is at times revealed that they are a compacted roll or zigzag of layers, as in the annexed cut (fig. 27), representing one of them twenty inches in breadth.* Such observations show why hornblendic metamorphic rocks, when containing little or no quartz, often fail of bedding, and look enough like igneous rocks to be frequently referred, without a question, to that class.

I have observed other examples on New York Island, and one of the most remarkable of them in the 11th Avenue Park, between 133d and 138th streets. The rock over the higher rocky portion of the Park, north of the center (as long known) is largely hornblende schist, in many parts epidotic. The beds are bent in zigzags, and sometimes vary 90° in strike in a few

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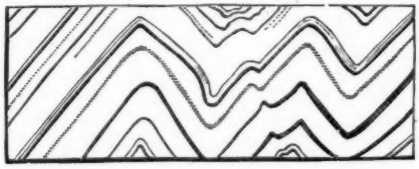

yards, owing to the small variously inclined flexures. Fig. 28 represents a portion of one of the zigzag surfaces, only twelve feet broad, north of the summit arbor. The mica schist and micaceous gneiss outcropping on 10th and 11th Avenues vary little in strike or dip. Such zigzags, however, although common in the hornblendic beds, are not confined to them.

* Such facts explain the statement of Dr. L. D. Gale respecting hornblende beds in the gneiss of 7th Avenue, south of McComb's Bridge (cited in Mather's N. Y. Report, p. 599): "in places hornblende so predominates as to cause the rock to assume a columnar structure."

The *crystalline limestone*—strictly dolomite—often contains so much dark brown or black mica in scales as to look like a thick-bedded gneiss; yet it betrays its true nature, here as usually elsewhere, by the occurrence of some crumbling surfaces. Besides tremolite, chlorite, with a little graphite and brown or black sphene, as before reported, the limestone contains white pyroxene in crystals, and green pyroxene in coccolite-like grains. The white crystals accompany tremolite in northern New York, near the King's Bridge Road,* and the coccolite variety characterizes part of the limestone of the "Mount Eden" region, north of Fleetwood Park. Orthoclase in cleavable pieces also is sometimes an impurity of the limestone; and pyrite is a common source of disintegration and iron-rust stains.

The limestone areas are in part low and marshy, owing to the easy destruction of the rock. But in some parts of the region there are long, broad ridges, a hundred feet or so in height. One of these ridges extends from Morrisania to Fordham, and many quarries have been opened in it. Another of them, equally prominent but of the less pure, gneiss-like limestone, passes through "Mount Eden," and has given occasion to the extravagant expression *Mount* in the name of this locality of prospective streets and houses.

After these general remarks, I proceed to the special facts connected with the limestone areas and the associated schists.

1. Limestone Area, No. 1.

A. *The portions of the Area in Westchester County.*—The general fact has been stated that, in this easternmost of the belts, the beds on the *eastern* side have a high *eastward* dip (figure 29), and on the *western* usually a high *westward* dip, corresponding with the idea that the beds make an anticlinal flexure. This steep dip continues on the eastern portion quite to the Harlem; but on the western, it varies in its northern part to 70° E., and south of Tremont station from 80° W. to 60° W., becoming 50° W. and less in local folds.

29.

The center of the belt from Fordham to Morrisania, where it commences to widen, has equally high dip; but south of this

* The crystals occur over the surface of the ground or rock where the limestone has crumbled from weathering. They are found in such places more easily than in the solid rock in which the accompanying crystals of tremolite tend to conceal or disguise them. They may be found half a mile south of King's Bridge, west of the King's Bridge Road.

The specimens from this locality were first recognized as pyroxene by the Abbé Haüy, after an examination of crystals sent him by Dr. Archibald Bruce, the editor of Bruce's Mineralogical Journal. The fact is reported in the last number of that Journal, published in 1814, on page 266.

there are undulations in the beds with dips of 45° to 30° and less, both eastward and westward, corresponding with a widening out of the anticlinal. These undulations (of which there are successions across the region) are well shown in Melrose, on Elton Avenue, above 159th Street (see map), and also near

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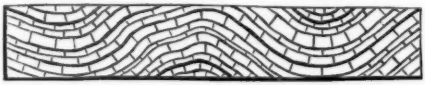

156th and 155th Streets, (fig. 30, representing a length of thirty-five yards) and on 150th Street, east of Cortlandt Avenue (fig. 31, representing a length of one hundred yards). There are outcrops also on 149th Street.

Farther south, about 140th Street, or below this, the limestone area is divided into two bands, an eastern and western, separated by schist—whether *underlying* or *overlying* schist, is considered beyond.

The outcrops of schist which prove this occur to the south, between 133d and 136th Streets, east of Willis Avenue (a spot marked by T-symbols on the map). The micaceous beds are undulating, with the dip in part small and varying from east to west, thus conforming in character to the limestone in the broad part of the anticlinal from 150th to 159th Streets. But on its eastern side near the limestone, that is, toward the east side of the anticlinal, the dip becomes high (70°–90° E.), conforming to that of the limestone.

The general facts respecting the Mott Haven band of limestone have been stated on page 360 of the last volume of this Journal.

The schist making the bluff or steep border along most of the west side of this limestone belt between Fordham and Morrisania is in general the quartzytic gneiss mentioned on page 428, though in some portions micaceous gneiss or hornblende schist.

B. *The limestone area in New York Island.*—The *eastern* of the two *limestone bands* does not come out to view south of Harlem River. It probably extends on beneath the low, now grass-covered, grounds of the west side of Randall Island, the once marshy coast opposite, and the channel of East River.

The *schist between the eastern and western bands* is exposed, north of 94th Street, at present, so far as I have found, only at a point on its eastern margin—the whole area, like that corresponding to it immediately north of Harlem River, having been low when civilization took possession. The one outcrop referred to occurs on East River, fifty feet north of 123d Street, and is exposed only at low tide. The micaceous gneiss is thin schistose, and the beds have a strike of N. 26° E., with the

dip 60° W. But farther south in the same line, that is, east of 3d Avenue, there are large outcrops of micaceous gneiss between 89th and 70th Streets, having the strike of the bedding N. 30° E. The beds are undulating, pitching at small angles both eastward and westward, except east of Avenue A toward

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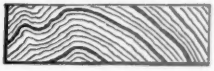

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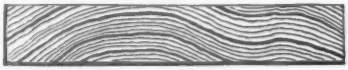


or near East River, where the dips become high—90° to 70° E. Fig. 32 represents a section on 75th Street, east of Avenue A; fig. 33, another on 77th Street, east of the same avenue; fig. 34, a portion of a section near East River.

34.

They thus accord in position with the similarly situated beds north of the Harlem, and would seem to indicate that the anticlinal is distinguishable at least to this distance, although it is hardly probable that the limestone continues so far down the river.

The *western* or *Mott Haven Limestone band* outcrops on the island between 118th and 124th Streets. The ledge of limestone with intercalated gneiss, north of 122d Street and east of and adjoining Lexington Avenue, first described by Mr. R. P. Stevens,* is the principal locality remaining. It is about 125 feet in breadth. His section of the limestone and schist contains an anticlinal flexure (now hardly distinct); but the mass exposed is certainly but a small part of the whole limestone band, and the flexure is evidently one of the local flexures so common in the stratification of that vicinity. The easternmost of the beds on 122d Street—which is about 35 feet wide and the purest—bends from N. 28° E. (the normal strike) to N. 54° E., and disappears beneath the adjoining yard and house; and probably the chief part of the limestone band is situated farther to the east along 3d Avenue. There are also three layers of limestone in the schist south of 122d Street. Besides these outcrops, there is much calcareous material in portions of the gneiss east of 4th Avenue between 118th and 120th Streets, as reported by Dr. Gale, and also on 124th Street, which localities lie to the west of the general range of the band.

As to the southern limit of the band there is no positive evidence. In view of the range of low land directly south along and east of 3d Avenue, and the outcrops of schist on the western side, it probably goes at least as far as 103d Street. Mr. R. P. Stevens, in the paper already referred to, states that limestone was found 18 feet below the surface, in 50th Street, between 3d and 4th Avenues, in excavating for a culvert; and this must belong to the same band, although the limestone is

* Annals of Lyc. Nat. Hist. of N. York, viii, 116, 1865.

interrupted over more or less of the interval between, by the gneiss.

The *schists west of this line of limestone* show themselves prominently on New York Island east of 4th Avenue between 129th and 130th Streets, and also both west and east farther south between 125th and 114th Streets. The beds have, in general, a dip of 60° to 50°. But there are broad and narrow undulations, with eastward and westward dips, as represented on the map, and illustrated as to general character in figs. 32, 33. Some portions are *fibrolitic*, as stated above; and this fact, taken in connection with the existence of the related cyanitic schist in the same line of bedding or strike near 42d and 45th Streets, is much in favor of the conclusion that this western overlying stratum of schist continues southward at least to 42d Street, or the vicinity of the Grand Central Station; and the fact that limestone exists in the same line of strike in 50th Street sustains this conclusion.

2. Limestone Area, No. 2.

A. *In Westchester County.*—The limestone area No. 2, or that of the valley of Cromwell's Creek (called also the Clove) joins that already described through the region of Fleetwood Park, as shown on the map. The northern limit of the belt is about two miles north of McComb's (or Central) Bridge. At this north extremity (in the region of the Manhattan House, M.) two valleys come up from the south and meet—the one just mentioned or "the Clove," and a more eastern, which passes into Fleetwood Park. The limestone of Morrisania extends westward over three-fourths of Fleetwood Park, and then northward (as the map shows) to join the limestone of the Cromwell Creek Valley. The high land between the two valleys forming the western side of Fleetwood Park consists mainly of schist. But farther north the schist makes only its western portion for 600 yards, and then narrows out leaving limestone alone, excepting an occasional intercalation of gneiss; and it is the kind of limestone already spoken of as firm and gneiss-like in aspect, and as containing much mica and in places green coccolite. From the ridge, the limestone extends across Cromwell Creek Valley; but it is here much less firm, and has in general small and varying dip. The beds are well displayed just east of Central Avenue a mile north of McComb's bridge (near Judge Smith's House) where the layers dip eastward from 30° to 70° and some are remarkably chloritic; and also less satisfactorily, half a mile farther north (opposite Sibbern's Club House, C.). Limestone of the firm thick-bedded kind is exposed to view also on the rising land east of the lower part of Cromwell's Creek and, at one place, in sight from the east end of the 161st Street bridge (the first north of McComb's), it has been quarried.

The *schist* east of the limestone along the west side of Fleetwood Park is nearly vertical in its bedding. That on the west side has, north of 167th Street, a high dip to the eastward, like the prevailing dip of the limestone; but south of this it becomes nearly vertical, and then westerly, and, within a fourth of a mile of McComb's bridge, the beds have widely varying dip with large contortions in the bedding, though westerly dips prevail; yet on the Harlem River side, the beds have greater regularity and stand nearly vertical. As shown below, they here face the Harlem River band of limestone.

B. *On New York Island.*—In New York, the limestone band of Cromwell Creek Valley is in sight only, as has been mentioned, between 131st and 133d Streets, about one hundred and forty yards east of 6th Avenue.* The width of the open lot north of 132d Street covered by the outcropping limestone is about fifty yards. Excepting a layer of schist six or seven feet thick the rock is all a coarsely crystalline limestone. Its average strike is N. 28° E., and the dip is mostly to the eastward 60°, but varying to 40° and less. There are also westward dips and, near the middle of the area, small local flexures.

To the south of 132d Street, where also there is an open lot, but narrower, the limestone shows itself at some places over the surface of the lot, and then disappears as it passes under a fence located half way to 131st Street; farther south it is covered by yards and buildings and other "city improvements." At the outcrops in this lot the beds are nearly vertical and have the direction N. 24°–28° E. Just east, a rocky ledge stands facing 132d Street, which, for seventy feet, fronts the open lot north of the street and is chiefly of limestone; the remaining thirty feet are of mica schist with a layer of limestone near its middle. The beds of the western part of the ledge are vertical, but those to the eastward are variously flexed. There is nothing at the locality to authorize a positive conclusion as to whether the body of the limestone band lies to the east or west of this locality.

How far this Cromwell Valley belt extends south of 131st Street is uncertain. The surface continues low to 124th Street, where rise the rocky ledges of Mt. Morris Park, and this may well be its southern limit. It is a question, however, whether it does not narrow and pass by the west side of the park, and, continuing southward, enter the low northeast corner of Central Park; in which case 103d Street would be its farthest possible limit since on 102d the schists of Central Park spread eastward across 5th Avenue, and so bring to an end the low valley-like area.

* This Journal, xx, 362 (Nov., 1880), where I cite a remark respecting it from R. P. Stevens in Ann. Lyc. Nat. Hist., N. Y., viii, 116.

3. Limestone Area, No. 3.

A. *The Limestone.*—The main facts respecting this area have already been given, and I have little to add except the evidence with reference to its extension down Harlem River. The map shows its position south of King's Bridge—its spreading over the Inwood Parade grounds,* the site selected for the proposed exposition of 1883—and its dividing into a *western* band which extends southward along the valley occupied by the King's Bridge Road, the chief highway of Northern New York, and an *eastern*, of greater length.

The western band I have not traced by outcrops beyond 194th Street; but the valley is so well defined by its western wall of schist and its flat bottom that there is little doubt as to the continuation of the limestone to 187th Street, and it may not end short of 183d Street, where the valley fades out.† The most southern locality of limestone mentioned by Dr. Gale and Professor Mather is just north of the Inwood Presbyterian Church, to the north of which all the old quarries of the region are situated.

Dr. Gale states, as quoted on page 519 of Mather's N. Y. Report, that "at 157th Street, about 100 feet west of 10th Avenue, the rock is entirely changed both in composition and structure; in composition it is a mixture of limestone and serpentine." I have not succeeded in finding this outcrop, probably because of changes since made in the surface by grading. The locality is nearly in the line that the western band would follow.

The existence of an eastern limestone band down Harlem River is placed beyond question by the fact—made known to me by Mr. Benjamin S. Church, Resident Engineer in charge of the Croton Water Works—that part of the piers of the Croton Aqueduct bridge, called High Bridge, rest on limestone. The map gives the position of the bridge. The following figure represents a sectional view of the structure reduced from a tracing obtained for me by Mr. Church at the Engineer's office in New York.‡

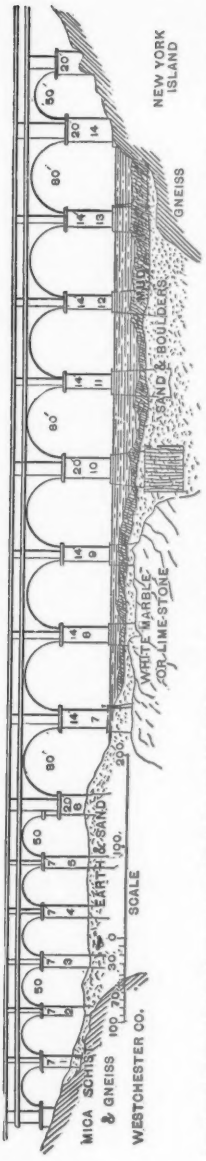
Of the piers, numbers 7, 8, 9 have the foundations planted on

* These grounds lie directly north of Sherman's Creek, east of the King's Bridge Road.

† Within this limestone area, east of the Inwood "Presbyterian Church," there is a small isolated area of micaceous gneiss, having a nearly northeast strike. It crosses the King's Bridge Road northeast of the church, and is about 225 yards long and 75 wide.

The magnesian character of this King's Bridge limestone was first determined by Mr. I. Cozzens, who states in his "Geological History of Manhattan Island," that it afforded him 28 per cent of carbonate of magnesia, and adds that he made epsom salts of it.

‡ The extremities of the bridge are left off in the copy here presented to reduce it to the length of the page, they being unessential to the illustration of the geological facts.



Sectional view of the Croton Aqueduct (or High) Bridge crossing the Harlem River between Westchester County and New York Island.

limestone, while numbers 3, 4, 5, 6, 10, 11, 12 are built on piles *which do not reach to rock.* In the case of piers 10, 11, 12, the stone foundations, as I have learned from the same authority, go down thirty feet below high water, and the piles fifty feet farther. The lower ends of these piles are consequently *eighty feet below high water level* and yet do not reach the bottom of the river channel. The depth of the excavation, which is thus proved to exist there, makes it extremely probable that the material excavated to such a depth was limestone and, therefore, that this rock extends eastward nearly to pier 13. In the case of pier No. 9, the limestone was reached at a depth of twenty-six feet at the southeast corner of the foundation and thirty-four feet at the northeast corner.

On such evidence, it is certain that the limestone passes the bridge, and exceedingly probable that it extends to the bend at 155th Street; and, since *the valley continues southward* in the same line along the old cove and streamlet shown on the map at the head of 8th Avenue, and, beyond this, along a range of what once were alluvial flats, but are now kitchen-garden plots, either side of the avenue, it is very probable that the limestone also continues.* These low lands or flats extend quite to Central Park, or 110th Street, and terminate in the depression adjoining its west corner, at 106th Street; whether the limestone also extends to the Park is among the doubtful points which only boring or excavation can now settle.

B. *Schist east of this Eastern (or Harlem River) limestone band.*—South of Mc Comb's Bridge, along 7th Avenue, there are ledges of micaceous gneiss which are continued to 135th Street; the beds are nearly vertical, the dip being 70° to 80° to the eastward to 90°, and the strike varies little from N. 28° E. The beds directly north of McComb's Bridge are

* Respecting this upper part of 8th Avenue, Dr. Gale says: "The valley through which 8th Avenue passes is throughout its course a perfect level and but a few feet above the level of Harlem River."

described above. On Harlem River about a mile north of this bridge (or 1½ mile south of King's Bridge), at Morris Dock Station, a light gray, fine-grained gneiss outcrops, which effervesces on the application of acid on account of the presence of calcareous or dolomitic material. This characteristic appears to show that it lies near the eastern border of the Harlem River limestone. North of this, to King's Bridge, there are no other outcrops.

C. *Schist west of the Harlem River or Eastern limestone band.*—At the north end of 10th avenue, south of Sherman's Creek, where grading has exposed a section of the high prominence once surmounted by "Fort George," the micaceous gneiss varies greatly in position, owing to irregular flexures, its dips changing from horizontal to vertical, and the direction from N.E. to N.W. But to the south along the avenue and between it and the river, down to 155th Street, the beds are quite uniform in position, being nearly vertical, 70° E. to 70° W., with the westing most prevalent, and the average strike N. 28° E. Farther south, the same steep or nearly vertical bedding continues to Central Park, the dip being generally 85° E. to 70° E., and the strike averaging N. 29° E.

4. Stratigraphical relations of the Limestone and Schist of the different Areas.

Mutual relations of the limestones.—From the statement of facts which has been made and the exhibition of them on the map, it is evident that the limestone of area No. 1 and that of No. 2 are one and the same mass or formation.

As to the identity with these of the limestone of the western area, No. 3, the proof is less positive, since No. 2 is nowhere visibly continuous with it, as it is with No. 1. I have suspected that there might be a connection in the bed of Harlem River at McComb's bridge, because of the varying flexures and low dips in the stratification just north of it (much like those of the schist south of Sherman's Creek, as shown on the map) and the contrast in this respect with the beds just south of the bridge. But after a careful study of the beds of both places, I think it improbable. Farther south, over the large area between 135th Street and 110th Street (or Central Park), the land is low, from a line east of 6th Avenue to one west of the 8th, so low that grading for streets has been carried on by filling, not by excavation, and no rocks in place have been encountered. Such features are of the kind natural to a limestone area, and suggest that a union of the limestone bands of the 8th and 6th avenues may take place somewhere between 135th and 120th Streets.

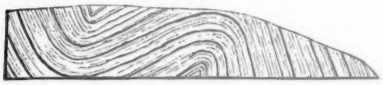
South of this flat country there is a sudden transition to gneissic hills—those of the Park; the limestone is absent. Nothing is seen of the 8th Avenue belt, or of that east of 6th Avenue. Whether the formation continues southward underneath the schist or not is a problem for further investigation. Some facts that may have a bearing on this point are mentioned on page 363 of the last volume of this Journal.

Thickness of the limestone.—The thickness of the limestone formation may be best derived from the northern part of Area No. 1, in Tremont. Since the beds stand nearly vertical, the thickness is about half the width, and therefore not far from 750 feet. From the section at High Bridge over the Harlem, the thickness there may be 700 feet, but probably is not over 600.

Flexures of the limestone and schists.—The fact that in Area No. 1, in Westchester County, the dips are westward on the western side (with exceptions to the north) and eastward, on the eastern, is sustained by my later as well as earlier observations, and seems to support the conclusion that the limestone makes an anticlinal or upward flexure. If this inference is correct, then the schist adjoining the limestone on its west side lies in a synclinal fold; and the broad part of the Cromwell Creek limestone band, in the vicinity of Mount Eden, and for the half mile south, is in an anticlinal: a single anticlinal only, although so wide; for the limestone in its western half is in low undulations where exposed farther south, and in its eastern generally dips 50° to 60°, and even less on Mount Eden. The limestone band along the Harlem includes but one thickness of the formation and may be the eastern band of either a very broad synclinal or anticlinal; probably the former, since westerly dips prevail on the Harlem River or eastern side of the schist and easterly on that of the Hudson.

But, on the other hand, the schists north of Tremont next west of limestone area No. 1, so generally dip *eastward* that it is a fair question whether the limestone of area No. 1 is not in a synclinal instead of an anticlinal. Again, at the extremity of this ridge of schist on the north side of Fleetwood Park (see map) the dip is westward on the west, and eastward on the east, as if the schist of this belt was in an anticlinal instead of synclinal.

35.



(Fig. 35 represents a portion of the eastern end of this section.) Further, the Mt. Eden limestone dips to the *westward* while the schists to the west of it, on the west side of Cromwell Creek, dip eastward; and this favors the idea of a synclinal for this limestone instead of an anticlinal.

These statements make it manifest that the question as to the actual character of the flexures is not easily cleared of the doubts that arise from local displacements and from varying positions of the axial plane of the flexures. Uncertainties exist also because of the covering of soil or drift over a large part of the region.

Although the plotting of sections from the obtainable facts (exhibited on the map) is consequently unsatisfactory work, I present the following sections (see page 441) as probably, in a general way, correct. The four sections cross the region from west (the left) to east: No. 1, through Tremont; 2, through Morrisania, along 168th Street, just north of Fleetwood Park; 3, through Melrose, along 159th Street; 4, through Mott Haven, along 138th Street. A section through Harlem would differ little from the last.

The sections speak for themselves, and to one who will examine them and the map together, and carefully compare each with the others, little explanation need be given. The limestone stratum is the blocked portion; that of the underlying schist is closely lined; that of the overlying schist more openly lined, with alternate broken lines.*

It is seen that, on this view of the flexures, the ridge of schist west of the limestone of Fordham and Tremont is part of an *underlying* stratum; and it is interesting to observe that the rock is to a large extent *quartzytic* gneiss, which suggests that it may correspond to the Potsdam sandstone and the schist associated with it in some regions (as near Peekskill and Tompkins' Cove). Its veins are mostly of quartz. The synclinal of the Cromwell's Creek limestone, shown in section 1, becomes covered with schist—*overlying* schist—south of Mt. Eden, as appears in section 2, and this ridge extends south to Mott Haven, appearing in sections 3 and 4, and beyond. It is in places fibrolitic to the north of Mott Haven, as well as to the south.

Whether the schist between Cromwell's Creek and the Harlem River limestone is in one, two, or more folds is uncertain; if in only one, the actual thickness of this underlying stratum of schist is large, and only a small lower portion of it is contained in the belt of schist west of Tremont.

The two westernmost bands of limestone in section 1 are those of Area No. 3,—the eastern or Harlem River band, and the western or King's Bridge Road band. They are represented as the opposite sides of a synclinal with *overlying* schist between. In the other sections only the eastern of the two occurs. This schist is mostly micaceous gneiss and mica schist, all the way to 110th Street, but contains in some parts hornblende schist.

* The local flexures in the beds are intended to show only that there are local flexures, not to represent special flexures.

5. Origin of various Topographical Features of New York Island.

Valleys and Low Areas.—From the distribution of the limestone, as exhibited on the map, and the fact of its easy wear or erosion, we derive explanations of several topographical features of New York Island and the adjoining region. For example we learn—

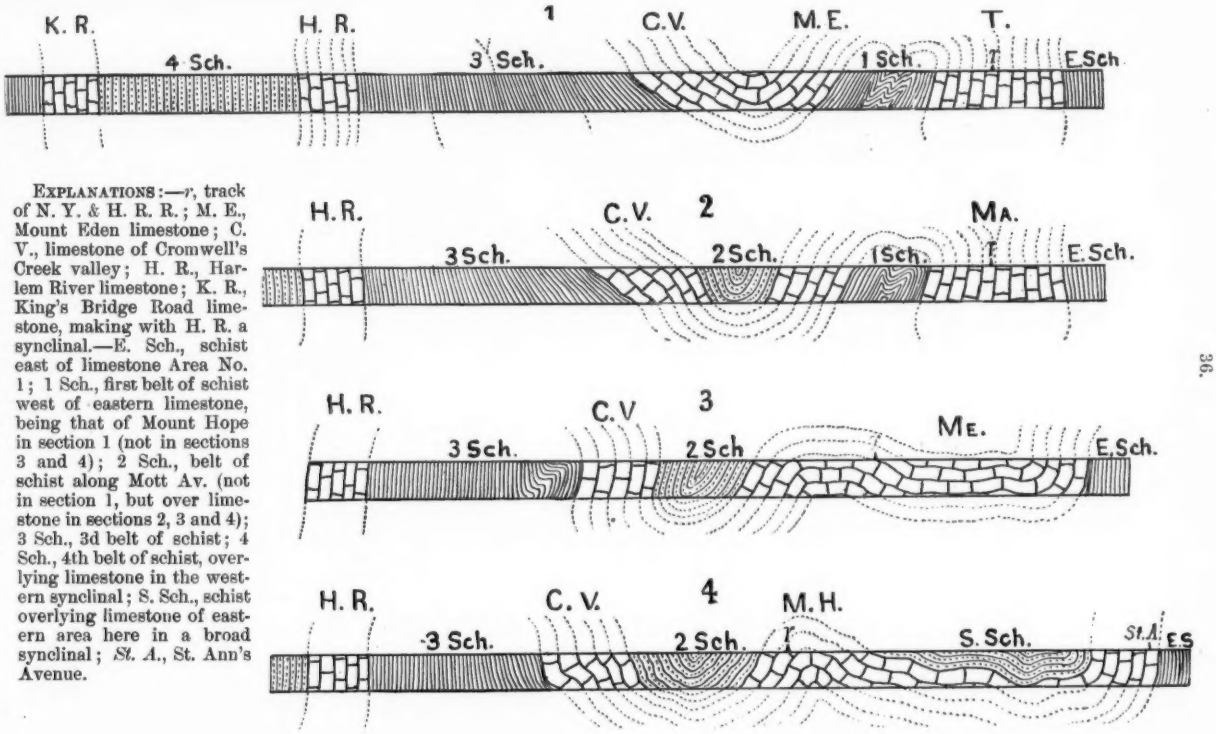
Why Harlem river has its present position and depth, and its north and south course; Why there is an "Eighth Avenue valley;" Why the "Inwood parade grounds" are a broad rolling region from the Harlem to the King's Bridge Road; Why, south of the Inwood Presbyterian Church, there was a King's Bridge Road valley, to fix the position of that old highway; Why Sherman's Creek bends around the Fort George heights; Why Cromwell's Creek exists and the valley or "Clove" to the north; Why Fleetwood Park is low and nearly flat, except its western side; Why Third Avenue in Harlem and the region east of it is low; Why wide flats (with small exceptions), extend from East River more than two-thirds of the way across the island, just north of Central Park; and, perhaps, why there is an East River channel.

The limestone lands that are not low may owe their height to the fact that erosion follows water courses; but, besides, the rock when in nearly vertical beds—usually the fact in such places—is generally of a firmer kind, because the pressure which gave the beds this position, served to compact the rock and so favored closer and better consolidation.

Trends of Ledges and City Avenues.—We also find a good reason for the precise direction given by the city surveyors to the New York avenues—it being the mean direction of the strike or direction of the bedding in the gneiss, and thence of the rocky ledges of the island. Many parts of the avenues in the northern half of the island have now a low even wall on one side or the other, made by a flat and nearly vertical cleavage-surface of the schist.*

The Manhattanville Valley.—The Manhattanville Valley (or Manhattanville and Harlem, as called by Dr. Gale), which cuts across the island obliquely from Manhattanville on the Hudson in a nearly southeastward direction, is one of its most extraordinary geological and topographical features, as mentioned on page 427. It reached East River, in a broad creek and marsh south of 108th Street; and so low lay the surface along it from one side of the island to the other, that in 1826 a canal was projected that should here connect Harlem River with the Hudson; and the canal was so far constructed that a celebration took place of the completion of the first lock.

* The avenues of New York run N. 28° 50½′ E. This parallelism between the strike of the beds and the avenues is referred to by Dr. Gale.



EXPLANATIONS:—*r*, track of N. Y. & H. R. R.; M. E., Mount Eden limestone; C. V., limestone of Cromwell's Creek valley; H. R., Harlem River limestone; K. R., King's Bridge Road limestone, making with H. R. a synclinal.—E. Sch., schist east of limestone Area No. 1; 1 Sch., first belt of schist west of eastern limestone, being that of Mount Hope in section 1 (not in sections 3 and 4); 2 Sch., belt of schist along Mott Av. (not in section 1, but over limestone in sections 2, 3 and 4); 3 Sch., 3d belt of schist; 4 Sch., 4th belt of schist, overlying limestone in the western synclinal; S. Sch., schist overlying limestone of eastern area here in a broad synclinal; *St. A.*, St. Ann's Avenue.

36.

The valley is supposed by Dr. Gale to have had a glacial origin, since it follows quite closely the course of the glacial grooves over the island. But the rocks point to its earlier existence and a profounder cause.

The general direction or strike of the beds of schist on the west side of 8th Avenue is about N. 29° E.—the dip being nearly vertical. But near this Manhattanville Valley, the strike, while normal to the north of it, to the south diverges from this, and in a way to show that *the valley probably had its initiation in an oblique wrenching and faulting of the rocks.* The map gives the facts, by means of the T symbols, better than can be done by words, representing along the high rocky land of Morning Side Park, an increase of easting to the northward up to the valley; and then, north of it, along St. Nicholas avenue, on the eastern side of the Convent Grounds, the usual or normal strikes. Besides this fact, derived from the strike of the rocks, there is another of apparent importance in the position of the rocky bluffs; for they are 100 yards farther west just south of the valley than they are north of it; in other words the alluvial flats—now garden plots—at the base of these bluffs extend 100 yards farther west along by the north part of the Morning Side Park than by the Convent Grounds.

There is still a third fact bearing on this question of a wrenching. Along the southwest part of the Convent Grounds, the beds of schist have an eastward pitch or dip of 50° to 60°, while 80° to 90° on the east side and to the north. The variation in the pitch of the beds might have resulted from a local anticlinal; but it is probably due to simply an irregular bending of the schist; for, on 10th Avenue, just northwest, the beds of schist become again nearly vertical, and quite so in the eastern part of the Park and north of it. Whatever be true as to the nature of the flexure, the facts support the idea of a wrenching in the schists of the vicinity; for these variations in pitch are not found south of the Manhattanville Valley.*

Finally, we may conclude that the pre-determinations of the fundamental features of New York Island date back to the era of the Lower Silurian, and to the epoch of mountain-making at its close. No other rocks that now remain have been added by subsequent geological operations excepting the loose or

* If the occurrence of limestone and serpentine on 157th Street near 10th Avenue, mentioned by Dr. Gale (see page 423) should be verified, it would give some support to the view that the western band of limestone of Area No. 3 is continued at intervals south of 183d Street; and in that case it is possible, though hardly probable, that it determined the course of the valley which passes southward through the "Park" between nearly vertically bedded schist, and thence along the west side of the Convent Grounds to Manhattanville Valley at 9th Avenue. Were such the fact, the western band of limestone, or its place in the synclinal, would there join the eastern band.

unconsolidated material of the surface. Fissures and faults may have occurred through subterranean movements; but the work of shaping its ledges has gone forward chiefly by the action of the sun, atmosphere, ocean, rivers, and ice; and the present condition, barring human encroachments, is the final result. Man's encroachments have dried up the Manhattanville stream and its marshes, excepting the small part that has been left as a pond in the northeast corner of Central Park, with its tributary rivulet; and the old alluvial flats that remain will soon grow houses in place of garden vegetables. In these and other ways the opportunity for the geological study of the island is rapidly passing. Whoever cares to see the disappearing limestone outcrops in Harlem, between 3d and 4th and 5th and 6th Avenues, must make his excursion soon.

[To be continued.]

ART. LV.—*Papers on Thermometry from the Winchester Observatory of Yale College;* by LEONARD WALDO.

[Continued from page 226.]

FOR the comparison of standard thermometers the observatory has had constructed by J. and H. J. Green, of New York, a water comparator which consists essentially of an outer and inner vessel with an intermediate space of $1{\cdot}5^{cm}$ filled with lamp-black. The outside cylinder is of copper and is 21^{cm} in diameter and 72^{cm} high. The inner cylinder is of brass. Two stop-cocks, one at the top and another at the bottom of the double cylinder, allow of the easy addition to or the lessening of, the water within. The agitation of the water is accomplished by a brass ring plunger $19{\cdot}2^{cm}$ in diameter and having a circular aperture of 7^{cm} to allow of the placing in position of the thermometer stand within. The thermometers are completely submerged, and after agitation the plunger is brought to rest at such a height that its disc forms with a perforated disc fixed to the thermometer stand, a metal diaphragm which prevents the circulation of the water during the reading of the thermometers.

The temperature being brought to the requisite height by a Bunsen burner beneath the comparator, the burner is withdrawn, the water is thoroughly agitated by the plunger, which is brought to rest finally with its disc in the same place as the stationary disc of the thermometer stand (through which the thermometers pass) and after a few moments the thermometers are read in the usual manner through a thick glass window in front. For high or low temperatures it is convenient to prevent radiation from or to the base of the cylinders by a mat which can be brought close against the base when the Bunsen

burner is removed.* With this apparatus, and with the assistance of Mr. O. T. Sherman, a comparison between the German standards "Fuess 89" and "Fuess 50," the French standards "Tonnelot 2584" and "Tonnelot 2585,"†

* The general principle is that of Pierre. Vid. Recherches sur la Thermometrie et sur la dilatation des Liquides, par J. I. Pierre. Caen, 1878. p. 57.

† Of the various methods proposed for the determination of the calibration errors of thermometers, those of Newmann and Bessel leave little to be desired for elegance or rigor of treatment. As a matter of practice, however, especially where many thermometers are to be furnished with calibration corrections, these methods require too much time except for the most refined work. The following method will give the calibration corrections at nine points (inclusive of the terminal points) equi-distant with three columns of mercury, or at seventeen points with four columns. The columns need be only approximately of the lengths of $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, etc., of the length to be calibrated respectively, and the principle of subdivision is employed rather than the super-addition of short calibrating columns. The objection to the method is that no weight is given to the summation of short mercury columns in determining the calibration corrections at long intervals. The increase of accuracy by the introduction of the short columns for multiples of their own length is doubtful, however, when the number of additional readings is considered.

Let l = the length of a column of mercury occupying the half of the distance between the freezing and boiling points in a thermometer nearest the freezing point.

l_1 = the length of a column of mercury occupying the half of the distance between the freezing and boiling points in a thermometer nearest the boiling point.

$\frac{1}{2}(l_1 - l) = \Delta_{\frac{8}{16}} = +a$ = the calibration correction for the point midway between the freezing and boiling point.

$\ldots \Delta_{\frac{2}{16}} \ldots \Delta_{\frac{4}{16}} \ldots \Delta_{\frac{1}{8}}$ = these corrections for points situated $\ldots \frac{2}{16} \ldots \frac{4}{16} \ldots \frac{1}{8}$th of the distance between the freezing and boiling point, assuming that the errors of calibration at the freezing and boiling points are zero.

b, b', = the calibration correction at the points corresponding to $\Delta_{\frac{4}{16}}$ and $\Delta_{\frac{12}{16}}$ on the assumption that the correction at the point $\Delta_{\frac{8}{16}}$ is zero.

c, c', c'', c''' = the calibration correction at the points corresponding to $\Delta_{\frac{2}{16}}$, $\Delta_{\frac{6}{16}}$, $\Delta_{\frac{10}{16}}$, $\Delta_{\frac{14}{16}}$ on the assumption that the corrections at the points $\Delta_{\frac{4}{16}}$ and $\Delta_{\frac{12}{16}}$ are each equal to zero.

d, d', d'' $\ldots$ d^{vii} = the calibration correction at the points corresponding to $\Delta_{\frac{1}{16}}$, $\Delta_{\frac{3}{16}}$, $\Delta_{\frac{5}{16}}$, $\ldots\ldots$ $\Delta_{\frac{15}{16}}$ on the assumption that the corrections at the points $\Delta_{\frac{2}{16}}$, $\Delta_{\frac{6}{16}}$, $\Delta_{\frac{10}{16}}$, $\Delta_{\frac{14}{16}}$ are each equal to zero.

And we may write, for a calibration determination at fifteen intermediate points, the following equations which admit of rapid and simple computation:

$$
\begin{aligned}
\Delta_{0} &= 0 \\
\Delta_{\frac{1}{16}} &= \tfrac{1}{8}a + \tfrac{1}{4}b + \tfrac{1}{2}c + d \\
\Delta_{\frac{2}{16}} &= \tfrac{2}{8}a + \tfrac{2}{4}b + c \\
\Delta_{\frac{3}{16}} &= \tfrac{3}{8}a + \tfrac{3}{4}b + \tfrac{1}{2}c + d' \\
\Delta_{\frac{4}{16}} &= \tfrac{4}{8}a + b \\
\Delta_{\frac{5}{16}} &= \tfrac{5}{8}a + \tfrac{3}{4}b + \tfrac{1}{2}c' + d'' \\
\Delta_{\frac{6}{16}} &= \tfrac{6}{8}a + \tfrac{2}{4}b \quad\quad c' \\
\Delta_{\frac{7}{16}} &= \tfrac{7}{8}a + \tfrac{1}{4}b + \tfrac{1}{2}c' + d''' \\
\Delta_{\frac{8}{16}} &= a \\
\Delta_{\frac{9}{16}} &= \tfrac{7}{8}a + \tfrac{1}{4}b' + \tfrac{1}{2}c'' + d^{\text{iv}} \\
&\ldots\ldots\ldots \\
\Delta_{\frac{12}{16}} &= \tfrac{4}{8}a + b' \\
&\ldots\ldots\ldots \\
\Delta_{\frac{15}{16}} &= \tfrac{1}{8}a + \tfrac{1}{4}b' + \tfrac{1}{2}c''' + d^{\text{vii}} \\
\Delta_{1} &= 0
\end{aligned}
$$

For a calibration computation for seven intermediate points, instead of fifteen, we simply omit the formulæ containing d, d', etc., and conversely the computation

and the Kew standards "Kew 578" and "Kew 584" was made. The usual precautions were taken to arrange the thermometer readings so as to free them from the effects of comparator radiation, and after correcting the observations for their known errors of calibration and zero points, the Fuess and Tonnelot readings were subtracted from the Kew readings and from the residuals thus obtained a curve was drawn from which the following corrections were obtained, expressed in Centigrade degrees.

Corrections (depending on the glass and the thermometer construction) necessary to reduce the Fuess and Tonnelot standards to the Kew standards.

Reading.	Δ Fuess 89 and Fuess 50.	Δ Tonnelot 2584 and Tonnelot 2585.	Reading.	Δ Fuess 89 and Fuess 50.	Δ Tonnelot 2584 and Tonnelot 2585.
0°	0°·00	0°·00	55°	−0°·20	−0°·24
5	−0·02	0·00	60	−0·19	−0·28
10	−0·03	0·00	65	−0·17	−0·28
15	−0·05	−0·02	70	−0·15	−0·27
20	−0·07	−0·05	75	−0·14	−0·26
25	−0·09	−0·09	80	−0·12	−0·25
30	−0·11	−0·11	85	−0·10	−0·22
35	−0·13	−0·14	90	−0·07	−0·19
40	−0·15	−0·17	95	−0·05	−0·09
45	−0·17	−0·20	100	0·00	0·00
50	−0·19	−0·22			

I have also received, through the courtesy of Professor Rowland, of the Johns Hopkins University, the notes of comparison made between Kew 584, Fuess 50, Tonnelot 2585 and the standards of his laboratory, Baudin 6163, Baudin 6165, Baudin

may be made to include thirty-one intermediate points by the insertion of another term, e, e', etc.

As an illustration, take the following example of the calibration of the thermometer "Tonnelot 2585," which is graduated in Fahrenheit's scale from the freezing to the boiling points and has $1° = 1{\cdot}8^{mm}$. The columns marked l_1 and l contain the lengths of the three columns of mercury at the respective places in the thermometer tube indicated by a, b, b', and c, c', c'', c''': of course l_1 merely indicates that it is the upper column and has a value of about 89°, 43° and 24° successively.

	l_1	l		$\Delta_0 =$ ·000	=0°·000 at 32°·0F.
$2a$	=89°·190−	89°·220.	$\therefore a$=−0°·015	and $\Delta_{\frac{2}{16}}$=−·004−·002+·018	=+·012 at 54·5F.
$2b$	= 42·743−	42·752	b=− 0·005	and $\Delta_{\frac{4}{16}}$=−·008−·005	=−·013 at 77·0F.
$2b'$	= 42·700−	42.720	b'=− 0·010	and $\Delta_{\frac{6}{16}}$=−·012−·002−·006	=−·020 at 99·5F.
$2c$	= 23·630−	23·593	c=+ 0·018	and $\Delta_{\frac{8}{16}}$=−·015	=−·015 at 122·0F.
$2c'$	= 23·600−	23·613	c'=− 0·006	and $\Delta_{\frac{10}{16}}$=−·012−·005+·002	=−·009 at 144·5F.
$2c''$	= 23·620−	23·617	c''=+ 0·002	and $\Delta_{\frac{12}{16}}$=−·008−·010	=−·018 at 167·0F.
$2c'''$	= 23·600−	23·612	c'''=− 0·006	and $\Delta_{\frac{14}{16}}$=−·004−·005−·006	=−·015 at 189·5F.
				$\Delta_1 =$ 0·000	= 0·000 at 212·0F.

The Tonnelot thermometers referred to were made in April, 1879, and have a graduation extending from + 5° to + 230° F. with about $1{\cdot}8^{mm}$ to 1°. They are divided to 0°·5 F., having a total length of about 455^{mm} with cylindrical bulbs about 40^{mm} long. They are beautifully calibrated and are otherwise highly creditable to their maker, Tonnelot, of Paris.

7316, and Kew 104, which afford the means of expressing the three first named thermometers in terms of the air thermometer used by Professor Rowland. After tabulating the corrected observations and referring each thermometer to Rowland's absolute scale* a combination of the Yale and Johns Hopkins comparisons gives as a probable value of the relation between these standards and the air thermometer, the following system of corrections to be applied to the Kew, Fuess and Tonnelot standards respectively.

Reading.	Tonnelot 2585.	Fuess 50.	Kew 584.
0°	0°·00	0°·00	The curve for this thermometer shows slight irregularities on both sides of the absolute scale, in no case giving a correction exceeding −0°·04 C., and generally within −0°·02 C. of it. Since to adopt these corrections would imply that Jolly's air thermometer gives correct indications to 0·1mm, I consider the comparison as uncertain, and assume that Kew 584 has a small undetermined negative correction to reduce its readings to the absolute scale between +25° and +75° C.
5	−0·02	−0·03	
10	−0·03	−0·05	
15	−0·05	−0·08	
20	−0·07	−0·10	
25	−0·09	−0·13	
30	−0·11	−0·15	
35	−0·13	−0·17	
40	−0·15	−0·18	
45	−0·17	−0·19	
50	−0·19	−0·21	
55	−0·20	−0·21	
60	−0·21	−0·20	
65	−0·20	−0·20	
70	−0·20	−0·19	
75	−0·18	−0·17	
80	−0·17	−0·14	
85	−0·14	−0·12	
90	−0·11	−0·09	
95	−0·05	−0·05	
100	0·00	0·00	

In order to examine into a small systematic difference which exists between the comparisons made by Professor Rowland and ourselves, an air thermometer, of the form shown in the cut, was placed in the comparator with the standards above described. This modified form of Jolly's thermometer consists of a large spherical bulb (about 5cm in diameter) with a capillary tube at *c* which serves a purpose in attaching the bulb to the brass plate *c f e* and is used as an entrance tube for dry air in filling. When filled the tube *c* is sealed in the blow-pipe flame. The capillary *b* ends in a barometer tube *d*, 5cm in length, at the lower end of which a rubber tube forms the connection with a long barometer tube, *f e*, of the same glass as *d*. Tube *f e* projects through an aperture in the top of the comparator and has a smooth vertical motion in a V-shaped trough in which it is held by springs. Its vertical motion is communicated by the hand of an assistant.

* Vid. On the Mechanical Equivalent of Heat. Proc. Am. Acad., Bost., 1880, p. 113.

The advantage of this form of air thermometer is that the whole of the apparatus is at the temperature of the comparator, and is placed in a medium which will give us with great precision the temperature of the mercury in the air thermometer tubes. The corrections for the air contained in the capillary tube and above the mercury in the small chamber become zero. There is also no necessity for the long capillary tubes and fragile joints which occur when the Jolly's air thermometer has its mercury columns outside of the comparator.

The disadvantage of this form is that above 40° C. the correction for the tension of mercury vapor in the columns is difficult to determine. I had hoped to give our own comparison with this air thermometer in this paper, but I have only had time to satisfy myself that we reach very nearly the same results as Professor Rowland has done before us. In a subsequent paper I hope to discuss this part of the question.

It will have been observed that the three forms of thermometers chosen are typical and represent the forms now in use by scientific men.

The general characteristics of the above classes of thermometers may be described as follows:

Designation.	Characteristics.
1. Kew standards.	Thick stems, medium sized cylindrical bulbs blown from a separate piece of glass and joined to the thermometer stem. This glass, however, is supposed to be from the same pot as the glass of which the stem is composed. Flint glass known as "Powell's best flint."
2. Fuess standards.	Thin stem, small cylindrical bulbs blown from the same glass. Detached porcelain scale. Glass unknown.
3. Tonnelot standards.	Medium stem, long cylindrical bulbs blown from the same glass. The comparison with the Johns Hopkins Baudin thermometers shows the glass to be practically the same in both.

From a consideration of the above comparisons we reach the following conclusions:

1. The Kew standards made from the glass known as "Powell's* best flint," and of the chemical and physical constitution of the Kew standards 578 and 584 are very nearly coincident with the air thermometer between the freezing and boiling points of water; the maximum correction not exceeding $-0°{\cdot}05$ C. and reaching its maximum probably in the vicinity of 60° C.

2. The Fuess standards have a maximum correction of about $-0°{\cdot}20$ C., which occurs at a point beyond the 50° point.

* Jas. Powell & Sons, Whitefriars Glass Works, Temple street, E. C., London. I have written to these gentlemen for the chemical constitution of this glass, but they are unwilling, presumably from business reasons, to state the proportions used in its manufacture.

3. The Tonnelot standards have a maximum correction of about −0°·25 C., which occurs at some point beyond 50°.

There has not yet been proposed a thermometer which can be used to supplant the mercurial. A slight experience with the air or non-mercurial liquid thermometers will satisfy the observer that they are too difficult to use for ordinary scientific work outside of researches in thermometry. The non-mercurial liquid thermometer wets the glass and absorbs air to such an extent as to always make it unreliable, though the peculiar errors depending on the glass itself are reduced to an exceedingly small amount owing to the large linear expansion of any liquid used for a thermometric substance as compared with mercury.

It becomes therefore of importance that we should have a glass of known constitution and methods of manufacture, for mercurial standards. It is not sufficient that we should know only the commercial name of the glass, because this seldom gives any good idea of its constitution. Presumably the chemical constitution of the glass is of more importance than its manipulation in manufacture, and it hardly seems just to science for the glass makers to decline to furnish such data regarding thermometer tubing as will best enable students to investigate the peculiarities of particular standards. The manufacturers could hardly suffer financially from such a revelation, since the manufacture of thermometer tubing is so largely a question of individual skill in drawing the tubing from the mass.

Out of a very large number from many makers which we have examined in this connection, it may be safely said that the glass used in the Kew thermometers (and in general in the best modern English thermometers) most nearly gives a mercurial standard agreeing with the air thermometer. The French and German glass differ in general $\frac{1}{4}$° C. from this standard at 50° C., and the best American glass now used in thermometers about the same amount.

For our own convenience in the preparation of standards we desire to pursue our inquiries far enough to determine if possible in how far the behavior of glass as a thermometric substance is affected by its constitution and its methods of manufacture. The present state of the matter leads to a confusion in the making and examination of standards which is perplexing alike to the maker and the student of science who has not the refined appliances necessary to refer every thermometer to the air standard.

After publishing the description of the Fuess standards at p. 227, I received a note from Dr. Fœrster asking me to give publicity to the following letter from Dr. Thiesen in reply to

Professor Rowland's views regarding the Geissler thermometers, expressed in his memoir referred to. I append to the letter a further defence by Professor Rowland of his views.

A letter from M. Thiesen replying to Rowland's criticism of the Geissler thermometers.

Herr Professor Rowland hat sich an mehreren Stellen seiner Abhandlung "*On the Mechanical Equivalent of Heat*," (Proc. Am. Ac. Arts and Sciences, Vol. XV.), in sehr starken Worten verurtheilend über die Geissler'schen Thermometer ausgesprochen. Es wird keiner eingehenden Vergleichung der Vorzüge und Nachtheile der von den verschiedenen Verfertigern herrührenden und in den einzelnen Ländern bevorzugten Formen des Quecksilberthermometers bedürfen, um nachzuweisen, dass das von Herrn Rowland gefällte Urtheil zu weit geht, da die beiden von Herrn Rowland gerügten Fehler der Geissler'schen Instrumente nicht derartige sind, dass sie zu ernsten Bedenken gegen den wissenschaftlichen Gebrauch dieser Instrumente Veranlassung geben.

Zunächst verwirft Herr Rowland das Geissler'sche Thermometer, weil dasselbe am Ende der Kapillarröhre kein Reservoir trägt.* Der Nutzen eines derartigen Reservoirs ist aus den von Herrn Rowland (Seite 79) angeführten Gründen anzuerkennen. Es erleichtert die Kalibrirung des Thermometers, es erlaubt, nach Walferdin's Vorgang das Instrument auch bei höhern Temperaturen zu gebrauchen, und es vermindert die Schädlichkeit der im Quecksilber zurückgebliebenen Spuren von Luft. Aus diesen Gründen sind auch bereits vor dem Erscheinen der Abhandlung des Herrn Rowland deutsche Fabrikanten auf den Nutzen dieses Reservoirs hingewiesen worden. Allein deshalb darf der Mangel eines Reservoirs nicht zur Verwerfung des Instrumentes führen. Auch beim Mangel eines Reservoirs gelingt die Kalibrirung eines Thermometers leicht und sicher. Herrn Professor W. Foerster zu Berlin sind zahlreiche, meist von Beamten der Kaiserlichen Normal-Aichungs-Kommission ausgeführte Kalibrirungen von Thermometern mittelst einer Anzahl (öfters über 20) abgetrennter Quecksilberfäden von genau bestimmter Länge, aber kein Fall bekannt, in welchem die Abtrennung eines Fadens nicht gelungen wäre. Der Gebrauch eines Thermometers bei höhern Temperaturen, als sie abgelesen werden können, wenn alles Quecksilber eine zusammenhängende Masse bildet, dürfte keinem wirklichen Bedürfnisse entsprechen und kann nicht zu genauen Resultaten führen, sobald der Eispunkt des Thermometers in seinem neuen Zustande nach Abtrennung einer Quantität des Quecksilbers nicht abgelesen werden kann. Die in den Geissler'schen Thermometern

* Seite 79: Geissler and Casella omit it (the reservoir), which should condemn their thermometers. Seite 117: The Geissler also had none, but I succeeded in separating a column. The absence of a reservoir at the top should immediately condemn a standard, for there is no certainty in the work done with it.

noch vorhandenen Spuren von Luft endlich können nur bei sehr engen Röhren Störungen verursachen.

Der zweite Fehler, welchen Herr Rowland dem Geissler'schen Thermometer vorwirft, ist seine von Rowland gefundene grosse Abweichung vom Luftthermometer.* Eine solche Abweichung wird nur dann schädlich wirken können, wenn sie übersehen wird; bestimmt man, wie Herr Rowland es that, die Abweichung vom Luftthermometer experimentell, so wird es wenig ausmachen, ob die an den Thermometerablesungen anzubringende Korrektion gross oder klein ist. Ausserdem aber ist, es muss ausgesprochen werden, die von Herrn Rowland gefundene Abweichung der einzelnen Thermometer von Luftthermometer ohne dauernde Bedeutung. Das — der leider auch in Deutschland bisher meist üblichen Rechnungsweise entsprechende — Verfahren Rowland's, die Ablesungen der Thermometer bei den verschiedenen Temperaturen mit einander zu verbinden, ohne der gleichzeitigen Aenderung des Eispunktes der Thermometer Rechnung zu tragen, führt zu Resultaten, welche vom Alter des Thermometers, von seiner Behandlung vor und dem *modus procedendi* während der Vergleichungen abhängen.† Resultate, welche wesentlich nur von der Natur des Thermometers abhängen, ergeben sich dagegen, wenn unmittelbar nach der Vergleichung bei den einzelnen Temperaturen der Eispunkt des Thermometers bestimmt und in Rechnung gezogen wird.‡ Wenn Herr Rowland sich die Mühe geben wollte, neuerdings das Geissler'sche Thermometer oder auch Baudin 6167, welches eine dem Geissler'schen ähnliche Korrektion ergab, auf 100° C. zu erwärmen und etwa mit einem der andern inzwischen mehrere Monate unberührten Baudin'schen Thermometer bei 0°, 50° und 100° C°. zu vergleichen, so dürfte er bei 50° eine wesentlich kleinere Differenz zwischen diesen Thermometern, vielleicht sogar eine von entgegengesetztem Zeichen als 1878 finden.

Zum Schlusse mag noch erwähnt werden, dass von Beobachtern, welche sich eingehender mit dem Quecksilberthermometer beschäftigt haben, auch andere Fehler der Geissler'schen Thermometer aufgefunden sind, welche mehr mit der Eigenart dieser Thermometer verknüpft sind, als die von Rowland gerügten Mängel. Diese Uebelstände sind zum Theil durch wesentliche Neuerungen, welche in der Fabrikation der deutschen Thermometer in den letzten Jahren gemacht wurden, beseitigt worden.§

Berlin, den 11. März 1881. Dr. M. THIESEN.

* Seite 76: which is the worst in this respect. Seite 118: The Geissler still seems to retain its preëminence as having the greatest error of the lot.

† Siehe die Aenderung des 0°–100° Intervalls des Kew standard, Seite 97.

‡ Vergl. Pernet "Beiträge zur Thermometrie in Carl's Repertorium für Experimentalphysik, Bd. XI, S. 257, München 1875," und namentlich die im Druck befindlichen "Metronomischen Beiträge No. 3. herausg. von W. Foerster, Berlin 1881," und eine ebenfalls im Druck befindliche Publikation des Bureau International des Poids et Mesures zu Sèvres.

§ Siehe Loewenherz "Bericht über die Wissenschaftlichen Instrumente auf der Berliner Gewerbeausstellung im Jahre 1879, Berlin 1880, Seite 213, 214."

Remarks by Professor Rowland on the preceding letter, in a communication dated Johns Hopkins University, April 29, 1881.

Through the kindness of Dr. Waldo, I have been allowed to see the above and would like to give a few words of explanation.

In reading what I had to say with respect to the Geissler thermometer, the reader should remember that I was not writing on general thermometry, but only on that part which should be useful to me in measuring *differences of temperature within the limits of* 0 *and* 45° C. And so I merely made a study of thermometers, their change of zero and other points, as it affected the problem which I had before me. I am well aware that there are formulæ for giving the changed readings of thermometers due to previous heating, but, according to well known principles in such cases, I prefered to eliminate such error by the proper use of the thermometer rather than trust to an uncertain theory.

In the course of my investigation I discovered the fact that the Geissler thermometers, especially the one I then used, departed more from the air thermometer than any other. Now the Geissler thermometer has been used for many years by physicists, principally German, *without* any reduction to the air thermometer. And this correction was so great, amounting to over 0°·3 C., for the specimen I used, at the 45° point, that I thought it right to call attention to the point. And I acknowledge that the picture was present in my mind of a physicist reading a thermometer from a distance by a telescope to avoid the heat of the body and parallax, and recording his results to thousandth of a degree, and all this on a thermometer having an error of 0°·3 C.! As Dr. Thiesen remarks: If one is to compare his thermometer with the air thermometer, the amount of correction is of little importance: but departure from the air thermometer is certainly not a recommendation and, indeed, must introduce slight errors. The most accurate readings which one can make on an air thermometer will vary several hundredths of a degree.

Hence we can never use with accuracy the direct comparison with the air thermometer but must express the difference of the two instruments by some formula of the form

$$\Delta = a + bt + ct^2 + \&c.$$

Should we take an infinite number of terms this formula would express all the irregularities of our observations. But by limiting the number of terms the curve of differences becomes smoother and smoother and the formula expresses less and less the irregularities of the experiment. The number of terms to be used is a matter of judgment, and this point I sought to determine by the use of the observations of Regnault and others. The rejection of the higher powers of t is more or less of an assumption founded on the fact that we are reasonably certain that the curve of differences between the mercurial and the air thermometer is a smooth curve. It is evident that the less the correction to be introduced the less the rejection of the higher powers of t will affect our results.

We now come to my criticism of the Geissler thermometer for not having a reservoir at the top. Dr. Thiesen has in some way misunderstood my principal reason for its presence. My reason was not that "es vermindert die Schädlichkeit der im Quecksilber zurückgebliebenen Spuren von Luft" but that only by its use can the mercury in the bulb be entirely free from air. Take a thermometer and turn it with the bulb on top. If the thermometer is large, in nine cases out of ten the mercury will separate and fall down: allow it to remain and observe the bubble-like vacuum in the bulb. Turn the bulb in various directions so as to, as it were, wash the whole interior of the bulb, and then bring the thermometer into a vertical position, keeping the bubble in sight. As the mercury flows back, the bubble diminishes and finally, in a good thermometer, almost disappears: but in most thermometers a good sized bubble of air, in some cases as large as the wire of a pin, remains. It is the most important function of a reservoir at the top to permit such manipulations as to drive all such air into the top reservoir and to make the mercury and the glass assume such perfect contact that the bulb can be turned uppermost without the mercury separating, even in thermometers of large size and with good generous bulbs. In many Geissler thermometers such a test might succeed, not on account of the freedom from air, but because the capillary tube and bulb are so small and the column so short that the capillary action is sufficient to prevent the fall. Now I think that a thermometer in which there is this layer of air around the mercury in the bulb must be uncertain in its action; hence my opinion is unaltered that all thermometers in which we cannot remove this layer or at least make certain of its absence should be rejected.

Furthermore, with respect to calibration, the reservoir is not essential to the calibration of thermometers whose range is 0 and 100° C. But my remarks apply better to those whose range is between 0 and 30° C. or 40° C. Here calibration is impossible with a short column at ordinary temperatures unless some of the mercury can be stored up in the reservoir so as to allow the column to move over the whole scale. And it is within this limit that thermometers are of the greatest value in the physical laboratory.

The other defects of the Geissler thermometer, the scale which was always coming loose, the metal cap which was never tight and always allowed water to enter, the small capillary tube which wandered with perfect irregularity from side to side over the scale, all these were so obvious that I confined my remarks to the more obscure errors.

Furthermore, I believe there is some error in most Geissler thermometers from the small size of the bulb and the capillary tube, and this I have mentioned on p. 124 of the paper referred to. Pfaundler and Platter, in a paper on the specific heat of water, in Poggendorff's Annalen for 1870, found an immense variation within small limits. In a subsequent paper* the authors

* Poggendorff's Annalen, cxli, p. 537.

traced this error to the lagging of the thermometer behind its true reading.

The authors used Geissler thermometers *graduated* to $\frac{1}{5}^{\circ}$ C.! In a series of experiments made by plunging the thermometer into water after slightly heating or cooling the thermometer so that in one case the mercury fell and the other rose to the the required point. When the thermometer fell about 6° or 8° C. it lagged behind 0°·0654 and when it rose 3° or 4° it lagged 0°·022, making a difference of 0°·087 C.! Now my thermometers made by Baudin show no effect of this kind. They indicate accurately the temperature whether they rise or fall to the given point, provided the interval is not too great. The fact then remains that a Geissler thermometer *graduated* to $\frac{1}{5}^{\circ}$ C. may be *uncertain* to 0°·087 C., while a Baudin graduated to mm., one mm. being from $\frac{1}{10}^{\circ}$ to $\frac{1}{14}^{\circ}$ C. is not uncertain to 0°·01 or 0°·02 C. May not the cause be found in the layer of air around the mercury of the bulb which cannot be removed without a reservoir at the top? Or may we not also look for such an effect from the minute size of the bore of the capillary tube which creates a different pressure in the bulb from a rising or falling meniscus? Possibly the two may be combined.

ART. LVI.—*On the Reduction of Air-pressure to Sea-level, and the Determination of Elevations by the Barometer;* by H. A. HAZEN, A.M.

IT is apparent that the two divisions of this subject are so intimately connected that the formula which may be determined for the one will apply to the other.

In the last number of this Journal, page 365, it has been shown that the barometric formula of Laplace does not prove satisfactory in making reductions of individual observations to sea-level, if the elevation of the station equals 6,000′. In continuing the discussion the effects of humidity and latitude are for the present omitted; neither can affect the results aimed at, for the reason that the corrections due to them, when applied, can only affect the final result by a small, nearly constant quantity.

We will determine first the exact variations, at some elevation, of the hights computed from Laplace, at different pressures and temperatures. The method proposed on page 364, which I have already quoted, has been adopted in constructing Table I. Valdobbia and Alessandria, inland stations of Italy, have been chosen, as mean daily observations for 8½ years at these stations have been published side by side in the Moncalieri Meteorological Bulletin. Valdobbia is about 8,200′

high, situated in latitude 46° north, and seventy miles from Alessandria, in 45° north latitude and 318′ high.

TABLE I.—(In millimeters).

	−6° C.	−3°.	0°.	3°.	6°.	9°.	12°.	15°.	18°.	21°.
550	744·0	743·9	741·1	739·8	....	....	....	....	....	....
555	752·0	749·5	746·6	745·2	744·1	742·5	....	....	....	....
560	757·1	755·6	753·9	752·1	750·0	748·2	746·2	744·7	743·0	....
565	762·5	761·0	759·6	758·1	755·3	754·4	752·3	750·3	744·5	....
570	769·0	763·0	764·8	763·0	761·5	759·0	758·1	756·1	754·6	753·1

In this table the first horizontal row of figures represents the mean temperature between the two stations, each vertical column contains a mean of all the pressures observed at the lower station for $3\frac{1}{2}$ years at the time of the mean temperature at the head of the column, hence the column headed 0° contains a mean of all the pressures at Alessandria between the mean temperatures of −1·5° C. and +1·5° C., distributed along the column according to the pressure at Valdobbia, as indicated on the left, the original table runs to single millimeters. It will now be seen that we have the mean temperature between the two stations and the mean pressure at the upper and lower stations for a range of 27° C. of temperature and 20mm. of pressure, from which we may compute, by Laplace, the difference of elevation of the two stations, as in Table II.

TABLE II.—(In meters).
Elevation of Valdobbia above Alessandria.

	−6° C.	−3°.	0°.	3°.	6°.	9°.	12°.	15°.	18°.	21°.
551	2380	2374	2396	2386	....	....	....	....	....	....
552	2376	2376	2376	2390	2396	....	....	....	....	....
553	2371	2376	2390	2387	2411	....	....	....	....	....
554	2379	2374	2381	2388	2391	....	....	....	....	....
555	2385	2378	2370	2382	2397	2405	....	....	....	....
556	2402	2375	2378	2381	2388	2407	....	....	....	....
557	2368	2375	2374	2396	2399	2411	2392	....	....	....
558	2362	2379	2383	2379	2396	2396	....	....	....	....
559	2360	2366	2373	2379	2379	2386	2395	2395	....	....
560	2356	2369	2377	2383	2388	2395	2399	2411	2419	....
561	2351	2364	2373	2377	2386	2395	2397	2407	2437	....
562	2342	2370	2376	2376	2382	2398	2393	2406	....	....
563	2351	2355	2374	2374	2387	2393	2400	2403	2419	....
564	2347	2359	2368	2365	2386	2388	2396	2409	2414	....
565	2343	2355	2374	2376	2373	2390	2393	2399	2417	....
566	2340	2345	2359	2369	2369	2384	2394	2397	2409	....
567	2340	2353	2357	2370	2378	2383	2388	2402	2408	2421
568	2331	2352	2357	2371	2367	2383	2389	2397	2407	2416
569	2320	2342	2354	2366	2356	2375	2389	2393	2402	2414
570	2331	2316	2351	2358	2369	2368	2385	2391	2399	2412

From this table it is evident that there is a great uniformity in the variation of the elevation as computed from Laplace.

The computed result is the smallest for a low temperature and high pressure, and largest for a high temperature and low pressure. Can these variations be accounted for?

All who have discussed this subject are agreed that some modification of the formula is necessary. R. S. Williamson has written a treatise upon this matter in which he explains certain changes which he has made in the temperature and pressure terms of the formula, but these did not give satisfactory results, and he concludes that owing to variations of climate at different places, no general formula can be obtained for all cases.

The latest researches on this subject in the United States, so far as known, have been made by Professor J. D. Whitney, of Harvard College, who published a very important addition to barometric hypsometry in 1874. Prof. Whitney confines his researches to the region lying west of the Rocky Mountains. On page 9 of his "Barometric Hypsometry" we find, "From the observed hights of the columns of mercury in two barometers at different altitudes, but not separated by any great distance horizontally, we have at once the weights of a column of air reaching from the lower instrument to the outer limit of the atmosphere and of that portion of the air-column which rises above the upper instrument. The weight of the column of air between the two instruments is therefore known, and it would seem at first sight as if trustworthy results, or, at least, a very close approximation to the truth might be obtained. Laplace was the first to propose a complete formula." On page 13 we find, "Laplace's original formula comprised four terms, which may be designated as the *pressure* term, including, as is usual, the principal numerical coëfficient; the *temperature* term; the correction for *latitude;* and the correction for the change in the hight of the mercury column in the barometer, caused by the *variation in the intensity of gravity* with increase of altitude." After an extended discussion entirely upon a theoretical basis, Prof. Whitney concludes, "The pressure term, at least, is to be considered essentially unalterable." He considers that all the variations may be due to the temperature term, and has prepared a set of tables for correcting altitudes, in the western portion of the United States, as computed from Laplace.

Let us examine these points: if the only motions of the atmosphere were in a vertical direction and due essentially to the temperature, the solution of the problem would appear not difficult.

At first sight it seems as though the *temperature* term would be the easiest determined and the one least liable to change, for the reason that the temperature is almost entirely affected by only one great invariable cause. Thus we find the same mean temperature in April and October of each year, the lowest in

January and the highest in July. If the temperature term only were at fault, we should expect to find a regularity in the variation of the difference of elevation as computed from the mean of each of the months, also the *same variation at all places;* that is, if we should find the highest result in July and the lowest in January in any one place, any theory which could be applied to the variation of the temperature at different altitudes must necessarily give in general the same results at all isolated peaks throughout the world; but neither of these suppositions is according to fact, as has been shown in the May number, page 363, where we see that the *highest* value of the elevation of Mt. Washington, above Portland, as computed from Laplace, was in March, and the *lowest* in August, whereas in the elevation of Pike's Peak above Dodge City, the *highest* value was in July and the *lowest* in December.

We may then consider that the temperature term will remain nearly constant so far as it is affected by the heat of the sun; this hypothesis will be strongly supported by a practical demonstration in the course of this discussion.

On the other hand, the pressure term is affected by a great variety of causes. In summer there is an upward motion of the atmosphere, the ocean relatively to the land is cool and the air moves toward the region that is coolest, while in winter exactly the reverse takes place. This may explain the facts just mentioned. Mt. Washington, near the coast, is very little affected by this motion, and the results differ but little in January and July.

There seems to be, also, a constant motion of the atmosphere toward the east, slower in summer than in winter. It has also been found in a large number of cases that the difference of elevation as computed from the mean of the March and April observations, is frequently greater than that from other months. This may be due to a general diminution of the pressure at the lower station, which does not seem to extend to an elevation of 6,000′; such a diminution has been found at over 500 stations in the middle latitudes, but only at the lower stations. It would certainly seem, then, that the pressure term is more liable to change than the temperature term.

In order to separate the various elements which enter into the formula of Laplace, the following method is proposed: If tables be constructed from Laplace according to the plan of the table on page 370, this Journal, last number, for each thousand feet of elevation, it will be possible to obtain the laws of variation of the reductions to sea-level and represent them by a formula which shall dispense with logarithms and separate the various terms.

The following formulæ are founded on such a plan:

$$\text{For } 1000' : C = 1''\cdot1675 - 0''.0389\,(30'' - p) - 0''\cdot00245\,(t - 32°) + 0''\cdot0000065\,(t - 32°)\,(t - 52°)$$

$$\text{For } 2000' : C = 2''\cdot3803 - 0''\cdot0794\,(30'' - p) - 0''\cdot00490\,(t - 32°) + 0''\cdot0000130\,(t - 32°)\,(t - 52°)$$

$$\text{For } 3000' : C = 3''\cdot6401 - 0''\cdot1214\,(30'' - p) - 0''\cdot00735\,(t - 32°) + 0''\cdot0000195\,(t - 32°)\,(t - 52°)$$

The temperature term might have been much simplified, but this harmonizes best with later work. These formulæ were constructed up to an elevation of 8,000′, and from a combination of the eight the following general formula was obtained:

$$C = \cdot0000000000003h^3 + [''\cdot000000021702 - 0''\cdot0000000008(30'' - p)]h^2 + [0''\cdot001145482 - 0''\cdot0000381\,(30'' - p) - 0''\cdot00000245(t - 32°) + 0''\cdot0000000065\,(t - 32°)\,(t - 52°)]h$$

in which C = reduction to sea, h is hight of station in feet, p is pressure at station, and t the mean temperature at the time of observation, between station and sea.

If, now, we assume a pressure of 30″ and consider the total hight above such a pressure, as proposed by Prof. Angot, of Paris, we may put $30'' - p$ for C in the above formula, and solving for h obtain the following expression, which is general for any altitude:

$$h = \frac{\sqrt{4b \times (30'' - p) + a^2} - a}{2b} - 0''\cdot0000000003h^3 \qquad (1).$$

in which $a = 0''\cdot001145482 - 0''\cdot00000245\,(t - 32°) + 0''\cdot0000000065\,(t - 32°)\,(t - 52°) - 0''\cdot0000381\,(30'' - p)$

and $b = 0''\cdot000000021702 - 0''\cdot0000000008\,(30'' - p)$.

In constructing the formula a slight change from a rigid value of Laplace has been made for a known variation at Mt. Washington. In applying the formula an approximate elevation is computed from the first term and a correction applied to this from the second term. Tables have been constructed for elevations from −200′ to 9,000′ by means of this formula.

The hight of Mt. Washington above Portland by various formulæ is given in Table III.

The results in column 4 vary the most, and show, as has already been suggested, that no general formula can be determined for all stations. The results in column 6 show the ease with which the original formula of Laplace may be modified for different places, also the accuracy of this general method of procedure. May it not be possible to determine a general formula from the actual observations in different places, which shall require but a slight and readily-determined change to make it applicable to any locality?

TABLE III.—Mt. Washington above Portland, true difference 6240′.

	Laplace.	Difference from mean.	Angot.	Difference from mean.	Hazen (1).	Difference from mean.
January	6264′	+16′	6329′	+80′	6245′	+ 2′
February	6268	+20	6299	+50	6242	− 1
March	6284	+36	6306	+57	6265	+22
April	6242	− 6	6244	− 5	6244	+ 1
May	6232	−16	6201	−48	6234	− 9
June	6233	−15	6201	−48	6236	− 7
July	6225	−23	6158	−91	6233	−10
August	6215	−33	6198	−51	6225	−18
September	6236	−12	6217	−32	6230	−13
October	6249	+ 1	6253	+ 4	6246	+ 3
November	6275	+27	6286	+37	6271	+28
December	6259	+11	6296	+47	6246	+ 3
Year	6256		6267		6241	
Mean 12 mo's	6248		6249		6243	

The following suggestion is made in the absence of any other: Let all the observations for a series of years, at an elevated and at a lower neighboring station, be grouped as has already been proposed, then determine a formula which shall best represent all the observations, or, in other words, the laws

TABLE IV.

Law of variation of the temperature term at different pressures, and of the pressure term at different temperatures, at Valdobbia and Great Saint Bernard.

Pressure.	Temperature term variation for each degree Centigrade.		Temperat'e.	Pressure term variation for each millimeter.	
	Val. and Al.	Ber. and Al.		Val. and Al.	Ber. and Al.
551mm	0·733mm	----	− 6°mm	0·18mm	·31mm
552	·610	----	− 3	·15	·13
553	·500	----	0	·20	·22
554	·633	----	3	·23	·24
555	·467	0·55mm	6	·23	·17
556	·767	·63	9	·25	·30
557	·547	·48	12	·22	·26
558	·613	·62	15	·10	·16
559	·640	·58	18	·12	·17
560	·590	·76	21	·00	·00
561	·570	·65			
562	·640	·58			
563	·650	·57			
564	·570	·58			
565	·543	·66			
566	·603	·55			
567	·547	·58			
568	·580	·54			
569	·503	·60			
570	·560	·65			
571	·590	·59			
572	·610	----			
573	·567	----			
Mean	·593	·598			

of variation, at any station, of pressures and temperatures at different temperatures and pressures.

It would seem that if there be taken a sufficient number of stations, near enough together, at different elevations, the above result might be attained.

There are very great difficulties in obtaining satisfactory results at present, owing to the great distance between stations and the lack of reliable elevations. In Table IV we find, in the case of reduction from a higher to a lower station, the law of the variation of the temperature term at different pressures and the law of the pressure term at different temperatures, as determined from a comparison of all the mean daily observations at Valdobbia and Alessandria during $3\frac{1}{2}$ years; comparisons are also given for the same time between Great St. Bernard and Alessandria.

There is a remarkable uniformity in the temperature term variation at all pressures at both stations, but the pressure term variation is subject to breaks and rather regularly diminishes as the temperature increases.

The following formulæ have been constructed from the actual observations at several elevations in Italy and Switzerland:

Great Saint Bernard and Geneva: $C = 9''{\cdot}68 - 0''{\cdot}22\,(30'' - p) - 0''{\cdot}014\,(t - 32°)$

Monte Cavo and Rome: $C = 3''{\cdot}66 - 0''{\cdot}10(30'' - p) - 0''{\cdot}0052(t - 32°)$

Mondovi and Alessandria: $C = 2''{\cdot}10 - 0''{\cdot}06(30'' - p) - 0''{\cdot}0027\,(t - 32°)$

and from these the general formula,

$$C = 0''{\cdot}0000000117h^2 + 0''{\cdot}0011068h - 0''{\cdot}000029(30'' - p)h - 0''{\cdot}0000016\,(t - 32°)h + 0''{\cdot}0214$$

$$h, \text{ in feet}, = \frac{\sqrt{4b(30'' - p - 0''{\cdot}0214) + a^2} - a}{2b} \qquad (2)$$

in this $a = 0''{\cdot}0011068 - 0''{\cdot}000029\,(30'' - p) - 0''{\cdot}0000016\,(t - 32°)$
and $b = 0''{\cdot}0000000117.$

Table V gives difference of elevation by various formulæ. The results by Angot are better than by Laplace. It will be noticed that the sixth column has been computed from a formula into which the original observations at Valdobbia have not entered and in so far goes to show the reliability of this method. The formula applies best to elevations of about 8000′.

TABLE V.—Valdobbia above Alessandria.

Month.	Laplace.	Difference from mean.	Angot.	Difference from mean.	Hazen (2).	Difference from mean.
January	7699′	−98′	7904′	+51′	7863′	− 6′
February	7796	− 1	7904	+51	7916	+47
March	7823	+26	7904	+51	7911	+42
April	7811	+14	7835	−18	7887	+18
May	7848	+51	7851	−2	7887	+18
June	7823	+26	7792	−61	7844	−25
July	7842	+45	7818	−35	7854	−15
August	7848	+51	7822	−31	7860	− 9
September	7827	+30	7861	+ 8	7860	− 9
October	7801	+ 4	7854	+ 1	7847	−22
November	7735	−62	7828	−25	7830	−39
December	7709	−88	7858	+ 5	7862	− 7
Year	7808		7851		7862	
Mean of months	7797		7853		7869	

The following formulæ are added:

Mount Washington and Portland $C = 6''{\cdot}82 - 0''{\cdot}12\,(30'' - p) - 0''{\cdot}012\,(t - 32°)$

Professor Whitney has made nearly three years' observations at Sacramento and Summit, California, stations 77 miles apart with a difference of altitude of 6989′. The formula at these stations is $C = 5''{\cdot}24 + 0''{\cdot}25\,(30'' - p) - 0''{\cdot}010\,(t - 32°)$, the reversal of the sign in the pressure term from minus to plus has been already noticed in the May number, page 366.

It has been shown, then,

1st. The formula of Laplace gives too small results at high pressures and low temperatures and too great at low pressures and high temperatures.

2d. The pressure term is more liable to variation than the temperature term.

3d. It is possible to so arrange the formula of Laplace as to separate the terms, and dispense with the use of logarithms.

4th. It is possible to construct a formula from the actual observations which shall give satisfactory results.

The following paragraphs have been taken from an article in "Nature" for April 14th, 1881 (just received), on *Periodic Oscillations of Barometric Pressure*, by J. ALLAN BROUN, F.R.S., (now deceased). They are of interest as confirming some of the views advanced in the above paper.

Sedgwick has said: ["To explain difficulties in these questions" (relating to pressure and temperature) "the atmospheric strata have been shuffled in accordance with laboratory experiments."]

"If we suppose that the attraction of gravity is not the only attraction which affects the pressure of the atmosphere, but that this pressure varies through some other attracting force such as an electric attraction of the sun depending upon the varying humidity of the air and this again depending on its temperature; we should find another method of relating the two variations which does not exist if gravitation alone is employed. It is quite certain that many physicists will not admit the idea of an electric attraction on our atmosphere in the present state of

our knowledge, hence the efforts to make expansion, and a shuffling of the atmospheric strata suffice. We must not, however, in our ignorance, attempt to force conclusions in opposition to facts, and if these can be satisfied more easily and with greater probabilites in its favor by the aid of the hypothesis of an electric attraction of the sun, that hypothesis will have a better claim to acceptation than the other. I shall here note a few facts which cannot be explained by thermic actions.

1. I have shown that on the average of many years' observation in our latitudes the mean pressure diminishes at the rate of 0″·038 of mercury for every one hundred miles we proceed toward the north. This has been called a gradient from the similar term used in railway slopes: but it is no slope, it is a level of a surface of equilibrium like that of the sea. It is the mean hights of the barometer at the sea-level which indicate the form, if we may so say, of the equilibrating atmosphere.

2. In India we have seen that the atmospheric pressure oscillates at each station even when these are quite near to each other, independently of the known laws of equilibrium of gases. When we turn to the semi-diurnal oscillation of the barometer we are only amused at the attempts made to explain it by shuffling the atmospheric strata. Nothing can be more certain than that the theories of expansion, or resistance to expansion and overflow, are the vain efforts to make the laws of nature agree with a theory. Over the great ocean within the tropics, where the diurnal variations of temperature are small and the air is absolutely without perceptible currents for days together, the barometer rises and falls a tenth of an inch twice in twenty-four hours with the regularity of the solar clock. The action of the sun on the whole atmosphere which produces this movement varies chiefly during the day hours at inland stations with the temperature oscillation, so that, as in the case of the annual variation, the fall of the barometer at 4 P.M. is greater in the same latitude as the temperature is higher. This variation occurs during the most complete calms; the smoke rises vertically from the plains of Tinnevelly; no current is visible in the motion of the clouds; yet the barometer falls at four in the morning as it did at four in the afternoon, only it falls less."

ART. LVII.—*Occurrence of a nodule of Chromite in the interior of compact Meteoric Iron from Cohahuila;* by J. LAWRENCE SMITH, Louisville, Ky.

THE masses of iron from Cohahuila that I have designated the Butcher Meteorites,* to distinguish them from other meteorites of the same locality, have already afforded me several most interesting and novel results; among them, concretions of aragonite on the exterior (doubtless formed after their fall from surrounding conditions), and, more particularly, the new and interesting mineral, daubréelite,† concreted in the interior of the troilite nodules that exist in this iron. A great number of sections have been cut and daubréelite is always found with its well defined characteristics.

Recently I have had made two additional large sections. They have furnished, however, but few nodules. One of these was a well-defined, symmetrically oval nodule, 17 mm. by 12 mm., its diameters situated 6 centimeters from the exterior surface, compact solid iron intervening between the surface and the nodule.

* This Journal, ii, Nov., 1871. † Ib., xvi, Oct., 1875.

I was at once struck with its being different from any nodule I had yet observed in meteoric iron. There was no troilite in it; and although black it was not graphite; so that I supposed it might consist entirely of daubréelite. But its luster was more vitreous than in this last mineral. On examining carefully with a lens, I found in the black material a few particles of a translucent mineral, some particles of which were almost colorless, and one or two of a greenish hue (doubtless magnesian silicate); and, besides, there were a few specks of iron only traceable by the magnet.

The nodule was virtually a black granular mass. As stated, it was first taken for daubréelite. The smallest particle rubbed fine and fused with borax gave the intense green of chrome; but, to my surprise, when the powder was heated in nitric acid over a water bath, not the slightest impression was made upon it, showing that it was not daubréelite, which is soluble in nitric acid leaving a dark green residue. Heating it in fused carbonate of soda in no way changed its insolubility in acids. These reactions convinced me that I had *chromite;* and on fusing 150 milligrams of the finely pulverized mineral with ten times its weight of bisulphate of soda, it was thoroughly attacked but not dissolved. On treating with water, and fusing the residue with carbonate of soda and niter, and proceeding with the analysis as is usual in the case of chromite, there was obtained,

Chromic oxide	62·71—$\dot{C}r$
Ferrous oxide	33·83—$\dot{F}e$

the iron oxide being in the solution from the fused mass, after treatment with bisulphate of soda. The composition thus found is that of chromite. Traces of magnesia, cobalt and silica were detected; the magnesia and silica doubtless came from the siliceous mineral already referred to, which is either enstatite or olivine.

The result of these observations, then, is to establish the existence of a new mineral concretion in the interior of meteoric iron; for while chromite has been known to be associated with meteorites, this is the first instance of its having been found embedded in this manner in the interior of meteoric iron. The fact thus increases the interest of the Butcher meteorites, which have furnished such beautiful and distinguishing concretions of two chrome minerals.

I should state that some of the particles of chromite, under the microscope and with very intense light, are feebly translucent and have a dark reddish purple color. This translucency of chromite has been observed by the assistant of the Professor of Geology in the College of France. The name of this assistant I do not now recollect and I cannot now place my hands on the results of his researches in this direction.

Art. LVIII.—*Upon the Production of Sound by Radiant Energy;* by Alexander Graham Bell.

[Read before the National Academy of Sciences, April 21, 1881.]

In a paper read before the American Association for the Advancement of Science, last August, I described certain experiments made by Mr. Sumner Tainter and myself which had resulted in the construction of a "*Photophone*," or apparatus for the production of sound by light;* and it will be my object to-day to describe the progress we have made in the investigation of photophonic phenomena since the date of this communication.

In my Boston paper the discovery was announced that thin disks of very many different substances *emitted sounds* when exposed to the action of a rapidly-interrupted beam of sunlight. The great variety of material used in these experiments led me to believe that sonorousness under such circumstances would be found to be a general property of all matter.

At that time we had failed to obtain audible effects from masses of the various substances which became sonorous in the condition of thin diaphragms, but this failure was explained upon the supposition that the molecular disturbance produced by the light was chiefly a surface action, and that under the circumstances of the experiments the vibration had to be transmitted through the mass of the substance in order to affect the ear. It was therefore supposed that, if we could lead to the ear air that was directly in contact with the illuminated surface, louder sounds might be obtained, and solid masses be found to be as sonorous as thin diaphragms. The first experiments made to verify this hypothesis pointed towards success. A beam of sunlight was focussed into one end of an open tube, the ear being placed at the other end. Upon interrupting the beam, a clear, musical tone was heard, the pitch of which depended upon the frequency of the interruption of the light and the loudness upon the material composing the tube.

At this stage our experiments were interrupted, as circumstances called me to Europe.

While in Paris a new form of the experiment occurred to my mind, which would not only enable us to investigate the sounds produced by masses, but would also permit us to test the more general proposition that *sonorousness, under the influence of intermittent light, is a property common to all matter.*

* Proceedings of American Association for the Advancement of Science, Aug. 27th, 1880; see, also, this Journal, vol. xx, p. 305; Journal of the American Electrical Society, vol, iii, p. 3; Journal of the Society of Telegraph Engineers and Electricians, vol. ix, p. 404; Annales de Chimie et de Physique, vol. xxi.

The substance to be tested was to be placed in the interior of a transparent vessel, made of some material which (like glass) is transparent to light, but practically opaque to sound.

Under such circumstances the light could get in, but the sound produced by the vibration of the substance could not get out. The audible effects could be studied by placing the ear in communication with the interior of the vessel by means of a hearing tube.

Some preliminary experiments were made in Paris to test this idea, and the results were so promising that they were communicated to the French Academy on the 11th of October, 1880, in a note read for me by M. Antoine Breguet.* Shortly afterwards I wrote to Mr. Tainter, suggesting that he should carry on the investigation in America, as circumstances prevented me from doing so myself in Europe. As these experiments seem to have formed the common starting point for a series of independent researches of the most important character, carried on simultaneously, in America by Mr. Tainter, and in Europe by M. Mercadier,† Prof. Tyndall,‡ W. E. Röntgen,§ and W. H. Preece,‖ I may be permitted to quote from my letter to Mr. Tainter the passage describing the experiments referred to:

"Metropolitan Hotel, Rue Cambon, Paris,
November 2, 1880.

"DEAR MR. TAINTER:

* * * "I have devised a method of producing sounds by the action of an intermittent beam of light from substances that cannot be obtained in the shape of thin diaphragms or in the tubular form; indeed, the method is specially adapted to testing the generality of the phenomenon we have discovered, as it can be adapted to solids, liquids, and gases.

"Place the substance to be experimented with in a glass test-tube, connect a rubber tube with the mouth of the test-tube, placing the other end of the pipe to the ear. Then focus the intermittent beam upon the substance in the tube. I have tried a large number of substances in this way with great success, although it is extremely difficult to get a glimpse of the sun here, and when it does shine the intensity of the light is not to be compared with that to be obtained in Washington. I got splendid effects from crystals of bichromate of potash, crystals of sulphate

* Comptes Rendus, vol. xcl, p. 595.

† "Notes on Radiophony," Comptes Rendus, Dec. 6 and 13, 1880; Feb. 21 and 28, 1881. See, also, Journal de Physique, vol. x, p. 53.

‡ "Action of an Intermittent Beam of Radiant Heat upon Gaseous Matter." Proc. Royal Society, Jan. 13, 1881, vol. xxxi, p. 307.

§ "On the tones which arise from the intermittent illumination of a gas." See Annalen der Phys. und Chemie, Jan., 1881, no. 1, p. 155.

‖ "On the Conversion of Radiant Energy into Sonorous Vibrations." Proc. Royal Society, March 10, 1881, vol. xxxi, p. 506.

of copper, and from tobacco smoke, A whole cigar placed in the test-tube produced a very loud sound. I could not hear anything from plain water, but when the water was discolored with ink a feeble sound was heard. I would suggest that you might repeat these experiments and extend the results," &c., &c.

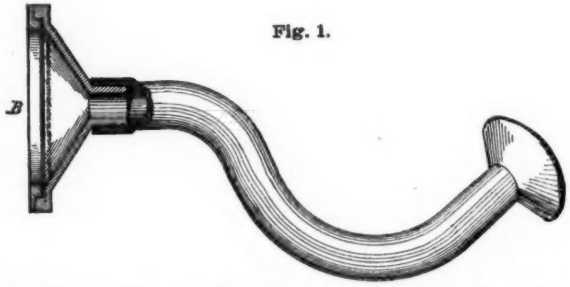
Experiments with Solids.

Upon my return to Washington in the early part of January,* Mr. Tainter communicated to me the results of the experiments he had made in my laboratory during my absence in Europe.

He had commenced by examining the sonorous properties of a vast number of substances enclosed in test-tubes in a simple empirical search for loud effects. He was thus led gradually to the discovery that cotton-wool, worsted, silk, and fibrous materials generally, produced much louder sounds than hard rigid bodies like crystals, or diaphragms such as we had hitherto used.

In order to study the effects under better circumstances he enclosed his materials in a conical cavity in a piece of brass closed by a flat plate of glass. A brass tube leading into the cavity served for connection with the hearing-tube. When this conical cavity was stuffed with worsted or other fibrous materials the sounds produced were much louder than when a test-tube was employed. This form of receiver is shown in figure 1.

Fig. 1.



Mr. Tainter next collected silks and worsteds of different colors, and speedily found that the darkest shades produced the best effects. Black worsted especially gave an extremely loud sound.

As white cotton-wool had proved itself equal, if not superior, to any other white fibrous material before tried, he was anxious to obtain colored specimens for comparison. Not having any at hand, however, he tried the effect of darkening some cotton-wool with lamp-black. Such a marked reinforcement of the sound resulted that he was induced to try lamp-black alone.

* On the 7th of January.

About a teaspoonful of lamp-black was placed in a test-tube and exposed to an intermittent beam of sunlight. The sound produced was much louder than any heard before.

Upon smoking a piece of plate-glass, and holding it in the intermittent beam with the lamp-black surface towards the sun, the sound produced was loud enough to be heard, with attention, in any part of the room. With the lamp-black surface turned from the sun the sound was much feebler.

Mr. Tainter repeated these experiments for me immediately upon my return to Washington, so that I might verify his results.

Upon smoking the interior of the conical cavity shown in figure 1, and then exposing it to the intermittent beam, with the glass lid in position as shown, the effect was perfectly startling. The sound was so loud as to be actually painful to an ear placed closely against the end of the hearing-tube. The sounds, however, were sensibly louder when we placed some smoked wire gauze in the receiver, as illustrated in the drawing, figure 1.

When the beam was thrown into a resonator, the interior of which had been smoked over a lamp, most curious alternations of sound and silence were observed. The interrupting disk was set rotating at a high rate of speed, and was then allowed to come gradually to rest. An extremely feeble musical tone was at first heard, which fell in pitch as the rate of interruption grew less. The loudness of the sound produced varied in the most interesting manner. Minor reinforcements were constantly occurring, which became more and more marked as the true pitch of the resonator was neared. When at last the frequency of interruption corresponded to the frequency of the fundamental of the resonator, the sound was so loud that it might have been heard by an audience of hundreds of people.

The effects produced by lamp-black seemed to me to be very extraordinary, especially as I had a distinct recollection of experiments made in the summer of 1880 with smoked diaphragms, in which no such reinforcement was noticed.

Upon examining the records of our past photophonic experiments we found in vol. vii, p. 57, the following note:

"Experiment V.—Mica diaphragm covered with lamp-black on side exposed to light.

"Result: distinct sound about same as without lamp-black.—*A. G. B., July 18th*, 1880.

"Verified the above, but think it somewhat louder than when used without lamp-black."—*S. T., July 18th*, 1880.

Upon repeating this old experiment we arrived at the same result as that noted. Little if any augmentation of sound re-

sulted from smoking the mica. In this experiment the effect was observed by placing the mica diaphragm against the ear and also by listening through a hearing-tube, one end of which was closed by the diaphragm. The sound was found to be more audible through the free air when the ear was placed as near to the lamp-black surface as it could be, brought without shading it. Thus the vibrations produced in lamp-black under the above circumstances do not appear to be communicated to any very appreciable extent to the diaphragm on which the lamp-black is deposited.

At the time of my communication to the American Association I had been unable to satisfy myself that the substances which had become sonorous under the direct influence of intermittent sunlight were capable of reproducing the sounds of articulate speech under the action of an undulatory beam from our photophonic transmitter. The difficulty in ascertaining this will be understood by considering that the sounds emitted by thin diaphragms and tubes were so feeble that it was impracticable to produce audible effects from substances in these conditions at any considerable distance from the transmitter; but it was equally impossible to judge of the effects produced by our articulate transmitter at a short distance away because the speaker's voice was directly audible through the air. The extremely loud sounds produced from lamp-black have enabled us to demonstrate the feasibility of using this substance in an articulating photophone in place of the electrical receiver formerly employed.

The drawing (fig. 2) illustrates the mode in which the experiment was conducted. The diaphragm of the transmitter (A) was only five centimeters in diameter, the diameter of the receiver (B) was also five centimeters, and the distance between the two was 40 meters, or 800 times the diameter of the transmitting diaphragm. We were unable to experiment at greater distances without a heliostat on account of the difficulty of keeping the light steadily directed on the receiver. Words and sentences spoken into the transmitter in a low tone of voice were audibly reproduced by the lamp-black receiver.

In fig. 3 is shown a mode of interrupting a beam of sunlight for producing distant effects without the use of lenses. Two similarly perforated disks are employed, one of which is set in rapid rotation, while the other remains stationary. This form of interrupter is also admirably adapted for work with artificial light. The receiver illustrated in the drawing consists of a parabolic reflector, in the focus of which is placed a glass vessel (A) containing lamp-black or other sensitive substance, and connected with a hearing-tube. The beam of light is interrupted by its passage through the two slotted disks shown at B,

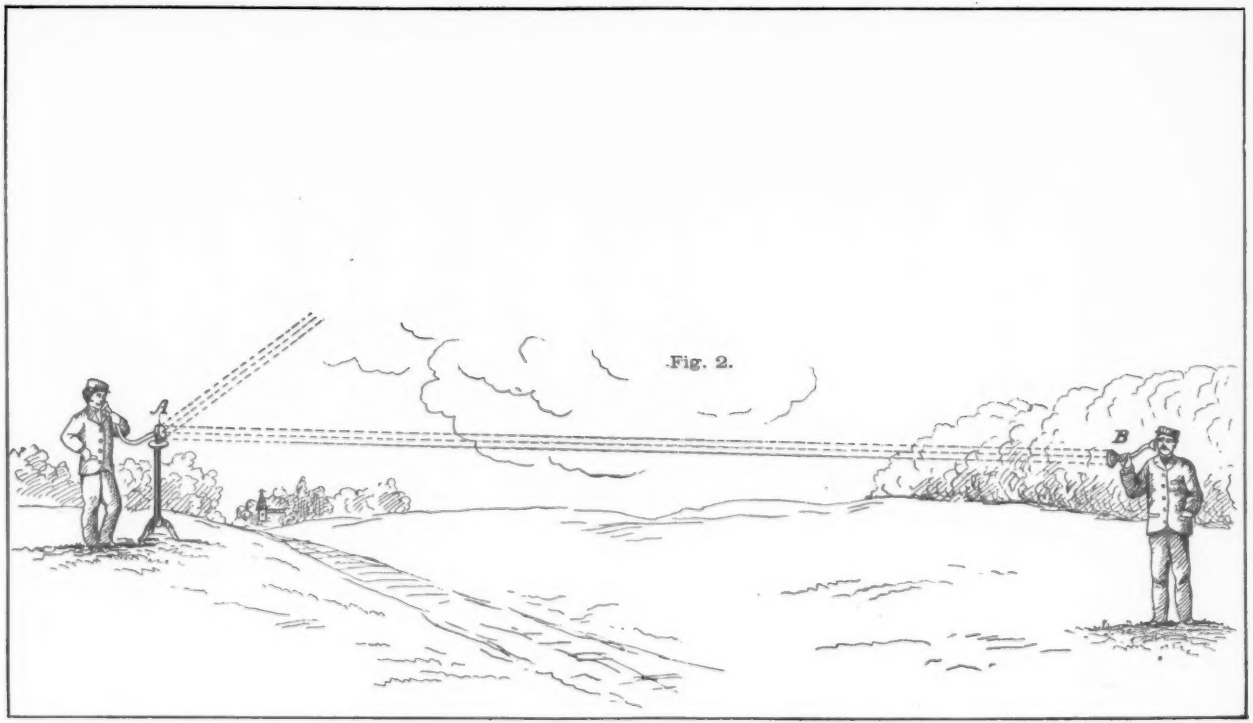


Fig. 2.

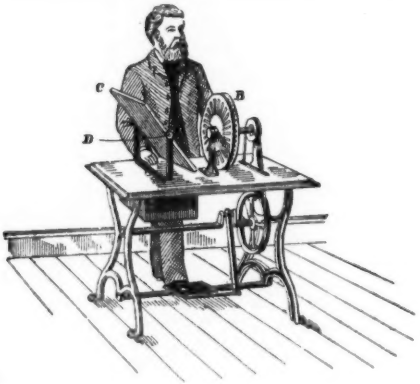
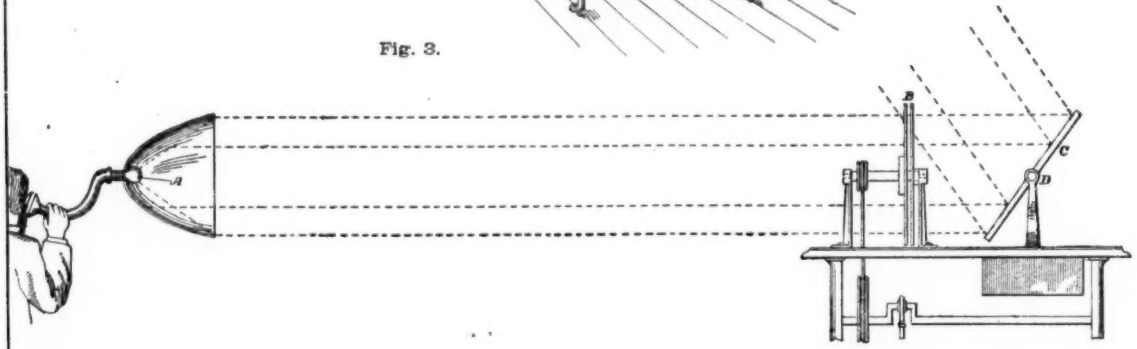


Fig. 3.



and in operating the instrument musical signals like the dots and dashes of the Morse alphabet are produced from the sensitive receiver (A) by slight motions of the mirror (C) about its axis (D).

In place of the parabolic reflector shown in the figure a conical reflector like that recommended by Professor Sylvanus Thompson * can be used, in which case a cylindrical glass vessel would be preferable to the flask (A) shown in the figure.

In regard to the sensitive materials that can be employed, our experiments indicate that in the case of solids the physical condition and the color markedly influence the intensity of the sonorous effects. *The loudest sounds are produced from substances in a loose, porous, spongy condition, and from those that have the darkest or most absorbent colors.*

The materials from which the best effects have been obtained are cotton-wool, worsted, fibrous materials generally, cork, sponge, platinum and other metals in a spongy condition, and lamp-black.

The loud sounds produced from such substances may perhaps be explained in the following manner: Let us consider, for example, the case of lamp-black—a substance which becomes heated by exposure to rays of all refrangibility. I look upon a mass of this substance as a sort of sponge, with its pores filled with air instead of water. When a beam of sunlight falls upon this mass, the particles of lamp-black are heated, and consequently expand, causing a contraction of the air-spaces or pores among them.

Under these circumstances a pulse of air should be expelled, just as we would squeeze out water from a sponge.

The force with which the air is expelled must be greatly increased by the expansion of the air itself, due to contact with the heated particles of lamp-black. When the light is cut off the converse process takes place. The lamp-black particles cool and contract, thus enlarging the air spaces among them, and the enclosed air also becomes cool. Under these circumstances a partial vacuum should be formed among the particles, and the outside air would then be absorbed, as water is by a sponge when the pressure of the hand is removed.

I imagine that in some such manner as this a wave of condensation is started in the atmosphere each time a beam of sunlight falls upon lamp-black, and a wave of rarefaction is originated when the light is cut off. *We can thus understand how it is that a substance like lamp-black produces intense sonorous vibrations in the surrounding air, while at the same time it communicates a very feeble vibration to the diaphragm or solid bed upon which it rests.*

* Phil. Mag., April, 1881, vol. xi, p. 286.

This curious fact was independently observed in England by Mr. Preece, and it led him to question whether, in our experiments with thin diaphragms, the sound heard was due to the vibration of the disk or (as Professor Hughes had suggested) to the expansion and contraction of the air in contact with the disk confined in the cavity behind the diaphragm. In his paper read before the Royal Society on the 10th of March, Mr. Preece describes experiments from which he claims to have proved that the effects are wholly due to the vibrations of the confined air, and that the *disks do not vibrate at all.*

I shall briefly state my reasons for disagreeing with him in this conclusion:

1. When an intermittent beam of sunlight is focussed upon a sheet of hard rubber or other material, a musical tone can be heard, not only by placing the ear immediately behind the part receiving the beam, but by placing it against any portion of the sheet, even though this may be a foot or more from the place acted upon by the light.

2. When the beam is thrown upon the diaphragm of a "Blake Transmitter," a loud musical tone is produced by a telephone connected in the same galvanic circuit with the carbon button (A,) fig. 4. Good effects are also produced when the carbon button (A) forms, with the battery (B,) a portion of the primary circuit of an induction coil, the telephone (C) being placed in the secondary circuit. In these cases the wooden box and mouth-piece of the transmitter should be removed, so that no air-cavities may be left on either side of the diaphragm.

It is evident, therefore, that in the case of thin disks a real vibration of the diaphragm is caused by the action of the intermittent beam, independently of any expansion and contraction of the air confined in the cavity behind the diaphragm.

Lord Rayleigh has shown mathematically that a to-and-fro vibration, of sufficient amplitude to produce an audible sound, would result from a periodical communication and abstraction of heat, and he says: "We may conclude, I think, that there is at present no reason for discarding the obvious explanation that the sounds in question are due to the bending of the plates under unequal heating." (Nature, xxiii, p. 274.)

Mr. Preece, however, seeks to prove that the sonorous effects cannot be explained upon this supposition; but his experimental data are not sufficient to support his conclusion. Mr. Preece expected that if Lord Rayleigh's explanation was correct, the expansion and contraction of a thin strip under the influence of an intermittent beam could be caused to open and close a galvanic circuit so as to produce a musical tone from a telephone in the circuit. But this was an inadequate way to

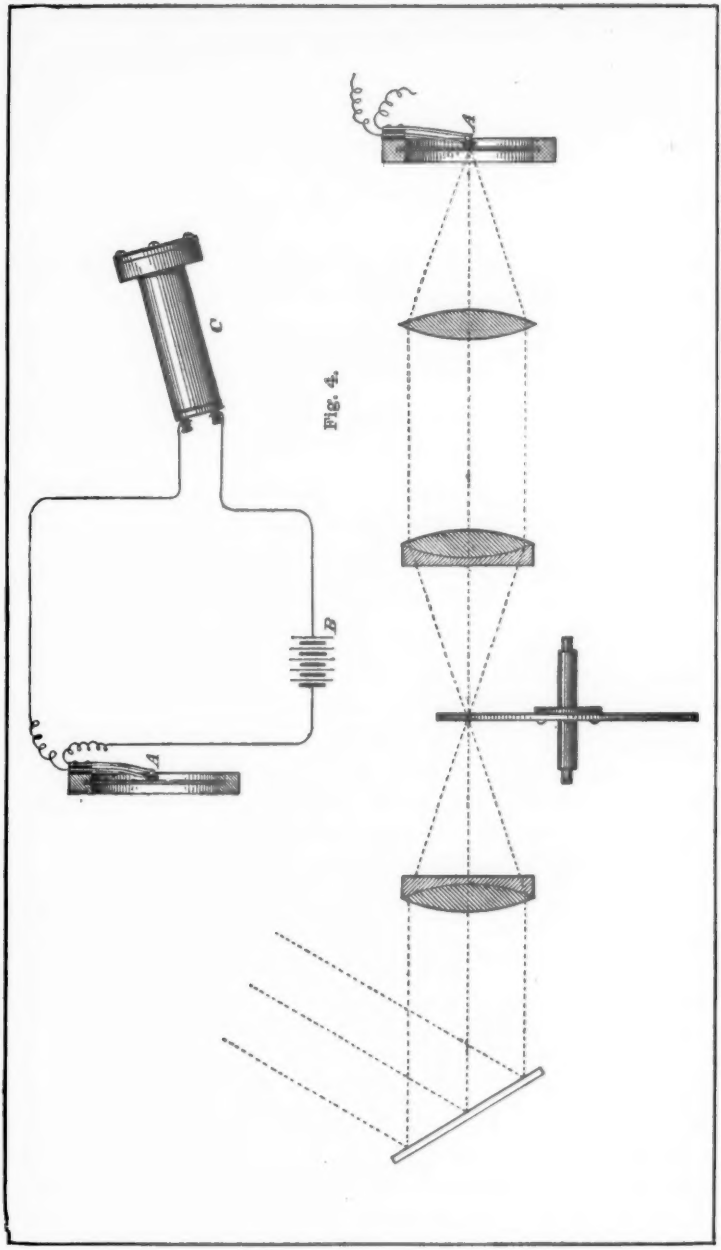


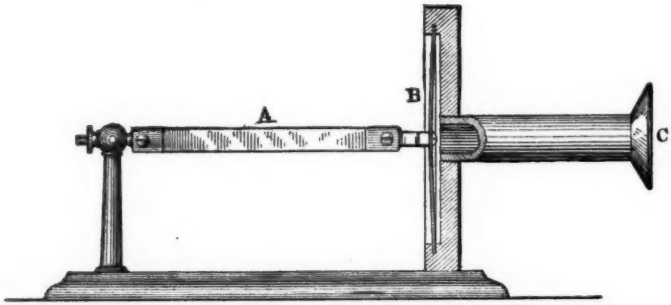
Fig. 4.

test the point at issue, for Lord Rayleigh has shown (Proc. of Roy. Soc., 1877) that an audible sound can be produced by a vibration whose amplitude is *less than a ten millionth of a centimeter*, and certainly such a vibration as that would not have sufficed to operate a "make-and-break contact" like that used by Mr. Preece. The negative results obtained by him cannot, therefore, be considered conclusive.

The following experiments (devised by Mr. Tainter) have given results decidedly more favorable to the theory of Lord Rayleigh than to that of Mr. Preece:

1. A strip (A) similar to that used in Mr. Preece's experiment was attached firmly to the center of an iron diaphragm (B,) as shown in figure 5, and was then pulled taut at right angles

Fig. 5.



to the plane of the diaphragm. When the intermittent beam was focussed upon the strip (A) a clear musical tone could be heard by applying the ear to the hearing-tube (C).

This seemed to indicate a rapid expansion and contraction of the substance under trial.

But a vibration of the diaphragm (B) would also have resulted if the thin strip (A) had acquired a to-and-fro motion, due either to the direct impact of the beam or to the sudden expansion of the air in contact with the strip.

2. To test whether this had been the case an additional strip (D) was attached by its central point only to the strip under trial, and was then submitted to the action of the beam, as shown in fig. 6.

It was presumed that if the vibration of the diaphragm (B) had been due to a *pushing force* acting on the strip (A), that the addition of the strip (D) would not interfere with the effect. But if, on the other hand, it had been due to the longitudinal expansion and contraction of the strip (A), the sound would cease, or at least be reduced. The beam of light falling upon

strip (D) was now interrupted as before by the rapid rotation of a perforated disk, which was allowed to come gradually to rest.

No sound was heard excepting at a certain speed of rotation, when a feeble musical tone became audible.

This result is confirmatory of the first.

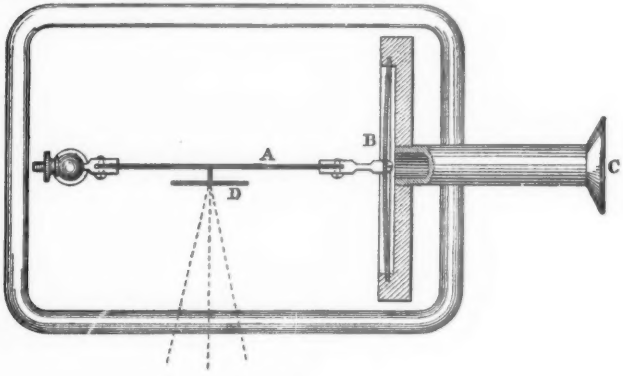


Fig. 6.

The audibility of the effect at a particular rate of interruption suggests the explanation that the strip D had a normal rate of vibration of its own.

When the frequency of the interruption of the light corresponded to this, the strip was probably thrown into vibration after the manner of a tuning-fork, in which case a to-and-fro vibration would be propagated down its stem or central support to the strip (A).

This indirectly proves the value of the experiment.

The list of solid substances that have been submitted to experiment in my laboratory is too long to be quoted here, and I shall merely say that we have not yet found one solid body that has failed to become sonorous under proper conditions of experiment.*

Experiments with Liquids.

The sounds produced by liquids are much more difficult to observe than those produced by solids. The high absorptive power possessed by most liquids would lead one to expect intense vibrations from the action of intermittent light, but the

* Carbon and thin microscope glass are mentioned in my Boston paper as non-responsive, and powdered chlorate of potash in the communication to the French Academy. (Comptes Rendus, vol. xcl, p. 595.) All these substances have since yielded sounds under more careful conditions of experiment.

number of sonorous liquids that have so far been found is extremely limited, and the sounds produced are so feeble as to be heard only by the greatest attention and under the best circumstances of experiment. In the experiments made in my laboratory a very long test-tube was filled with the liquid under examination, and a flexible rubber tube was slipped over the mouth far enough down to prevent the possibility of any light reaching the vapor above the surface. Precautions were also taken to prevent reflection from the bottom of the test-tube. An intermittent beam of sunlight was then focussed upon the liquid in the middle portion of the test-tube by means of a lens of large diameter.

Results.

Clear water	No sound audible.
Water discolored by ink	Feeble sound.
Mercury	No sound heard.
Sulphuric ether*	Feeble, but distinct sound.
Ammonia	" " " "
Ammonio-sulphate of copper	" " " "
Writing ink	" " " "
Indigo in sulphuric acid	" " " "
Chloride of copper*	" " " "

The liquids distinguished by an asterisk gave the best sounds.

Acoustic vibrations are always much enfeebled in passing from liquids to gases, and it is probable that a form of experiment may be devised which will yield better results by communicating the vibrations of the liquid to the ear through the medium of a solid rod.

Experiments with Gaseous Matter.

On the 29th of November, 1880, I had the pleasure of showing to Professor Tyndall in the laboratory of the Royal Institution the experiments described in the letter to Mr. Tainter, from which I have quoted above, and Professor Tyndall at once expressed the opinion that the sounds were due to rapid changes of temperature in the body submitted to the action of the beam. Finding that no experiments had been made at that time to test the sonorous properties of different gases, he suggested filling one test-tube with the vapor of sulphuric ether (a good absorbent of heat), and another with the vapor of bisulphide of carbon (a poor absorbent), and he predicted that if any sound was heard it would be louder in the former case than in the latter.

The experiment was immediately made, and the result verified the prediction.

Since the publication of the memoirs of Röntgen* and Tyndall† we have repeated these experiments, and have extended the inquiry to a number of other gaseous bodies, obtaining in every case similar results to those noted in the memoirs referred to.

The vapors of the following substances were found to be highly sonorous in the intermittent beam: water vapor, coal gas, sulphuric ether, alcohol, ammonia, amylene, ethyl bromide, diethylamene, mercury, iodine, and peroxide of nitrogen. The loudest sounds were obtained from iodine and peroxide of nitrogen.

I have now shown that sounds are produced by the direct action of intermittent sunlight from substances in every physical condition (solid, liquid, and gaseous), and the probability is therefore very greatly increased that sonorousness under such circumstances will be found to be a universal property of matter.

Upon Substitutes for Selenium in Electrical Receivers.

At the time of my communication to the American Association the loudest effects obtained were produced by the use of selenium, arranged in a cell of suitable construction, and placed in a galvanic circuit with a telephone. Upon allowing an intermittent beam of sunlight to fall upon the selenium a musical tone of great intensity was produced from the telephone connected with it.

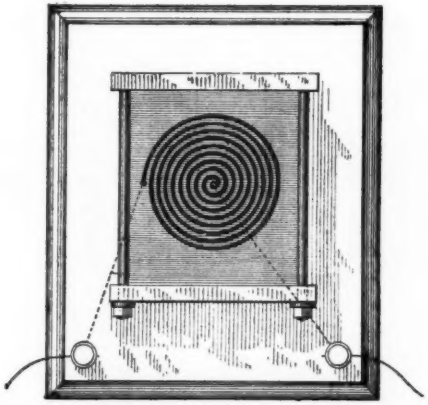
But the selenium was very inconstant in its action. Two pieces of selenium (even of the same stick) seldom yielded the same results under identical circumstances of annealing, etc. While in Europe last autumn, Dr. Chichester Bell, of University College, London, suggested to me that this inconstancy of result might be due to chemical impurities in the selenium used. Dr. Bell has since visited my laboratory in Washington, and has made a chemical examination of the various samples of selenium I had collected from different parts of the world. As I understand it to be his intention to publish the results of this analysis very soon, I shall make no further mention of his investigation than to state that he has found sulphur, iron, lead, and arsenic in the so-called "selenium," with traces of organic matter; that a quantitative examination has revealed the fact that sulphur constitutes nearly one per cent of the whole mass; and that when these impurities are eliminated the selenium appears to be more constant in its action and more sensitive to light.

Professor W. G. Adams‡ has shown that tellurium, like

* Ann. der Phys. und Chem., 1881, No. 1, p. 155.
† Proc. Roy. Soc., vol. xxxi, p. 307.
‡ Proc. Roy. Soc., vol. xxiv, p. 163.

selenium, has its electrical resistance affected by light, and we have attempted to utilize this substance in place of selenium. The arrangement of cell (shown in fig. 7) was constructed for this purpose in the early part of 1880; but we failed at that

Fig. 7.



time to obtain any indications of sensitiveness with a reflecting galvanometer. We have since found, however, that when this tellurium spiral is connected in circuit with a galvanic battery and telephone, and exposed to the action of an intermittent beam of sunlight, a distinct musical tone is produced by the telephone. The audible effect is much increased by placing the tellurium cell with the battery in the primary circuit of an induction coil, and placing the telephone in the secondary circuit.

The enormously high resistance of selenium and the extremely low resistance of tellurium suggested the thought that an alloy of these two substances might possess intermediate electrical properties. We have accordingly mixed together selenium and tellurium in different proportions, and while we do not feel warranted at the present time in making definite statements concerning the results, I may say that such alloys have proved to be sensitive to the action of light.

It occurred to Mr. Tainter before my return to Washington last January that the very great molecular disturbance produced in lamp-black by the action of intermittent sunlight should produce a corresponding disturbance in an electrical current passed through it, in which case lamp-black could be employed in place of selenium in an electrical receiver. This has

turned out to be the case, and the importance of the discovery is very great, especially when we consider the expense of such rare substances as selenium and tellurium.

The form of lamp-black cell we have found most effective is shown in fig. 8. Silver is deposited upon a plate of glass, and a zigzag line is then scratched through the film, as shown,

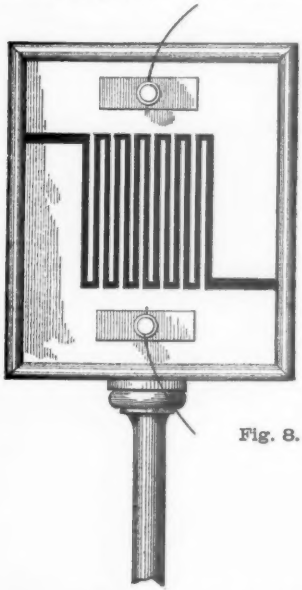


Fig. 8.

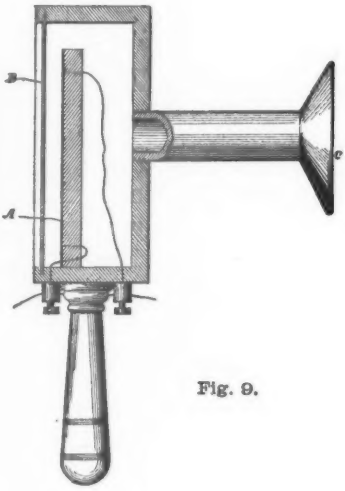


Fig. 9.

dividing the silver surface into two portions insulated from one another, having the form of two combs with interlocking teeth.

Each comb is attached to a screw-cup, so that the cell can be placed in an electrical circuit when required. The surface is then smoked until a good film of lamp-black is obtained, filling the interstices between the teeth of the silver combs. When the lamp-black cell is connected with a telephone and galvanic battery, and exposed to the influence of an intermittent beam of sunlight, a loud musical tone is produced by the telephone. This result seems to be due rather to the physical condition than to the nature of the conducting material employed, as metals in a spongy condition produce similar effects. For instance, when an electrical current is passed through spongy platinum while it is exposed to intermittent sunlight, a distinct musical tone is produced by a telephone in the same circuit. In all such cases the effect is increased by the use of an induction coil; and the sensitive cells can be employed for the

reproduction of articulate speech as well as for the production of musical sounds.

We have also found that loud sounds are produced from lamp-black by passing through it an intermittent electrical current; and that it can be used as a telephonic receiver for the reproduction of articulate speech by electrical means.

A convenient mode of arranging a lamp-black cell for experimental purposes is shown in fig. 9. When an intermittent current is passed through the lamp-black (A,) or when an intermittent beam of sunlight falls upon it through the glass plate B, a loud musical tone can be heard by applying the ear to the hearing-tube C. When the light and the electrical current act simultaneously, two musical tones are perceived, which produce beats when nearly of the same pitch. By proper arrangements a complete interference of sound can undoubtedly be produced.

Upon the measurement of the Sonorous Effects produced by different substances.

We have observed that different substances produce sounds of very different intensities under similar circumstances of experiment, and it has appeared to us that very valuable information might be obtained if we could measure the audible effects produced. For this purpose we have constructed several different forms of apparatus for studying the effects, but as our researches are not yet complete, I shall confine myself to a simple description of some of the forms of apparatus we have devised.

When a beam of light is brought to a focus by means of a lens, the beam diverging from the focal point becomes weaker as the distance increases in a calculable degree. Hence, if we can determine the distances from the focal point at which two different substances emit sounds of equal intensity, we can calculate their relative sonorous powers.

Preliminary experiments were made by Mr. Tainter during my absence in Europe to ascertain the distance from the focal point of a lens at which the sound produced by a substance became inaudible. A few of the results obtained will show the enormous differences existing between different substances in this respect.

Mr. Tainter was convinced from these experiments that this field of research promised valuable results, and he at once devised an apparatus for studying the effects, which he described to me upon my return from Europe. The apparatus has since been constructed and I take great pleasure in showing it to you to-day.

Distance from Focal Point of Lens at which Sounds became Inaudible with different substances.

Zinc diaphragm, (polished)	1·51[m]
Hard rubber diaphragm	1·90
Tin-foil "	2·00
Telephone " (Japanned iron)	2·15
Zinc " (unpolished)	2·15
White silk, (In receiver shown in fig. 1)	3·10
White worsted, " " " "	4·01
Yellow worsted, " " " "	4·06
Yellow silk, " " " "	4·13
White cotton-wool, " " " "	4·38
Green silk, " " " "	4·52
Blue worsted, " " " "	4·69
Purple silk, " " " "	4·82
Brown silk, " " " "	5·02
Black silk, " " " "	5·21
Red silk, " " " "	5·24
Black worsted, " " " "	6·50
Lamp-black. In this case the limit of audibility could not be determined on account of want of space. Sound perfectly audible at a distance of	10·00

(1.) A beam of light is received by two similar lenses (A B, fig. 10,) which bring the light to a focus on either side of the interrupting disk (C). The two substances, whose sonorous powers are to be compared, are placed in the receiving vessels (D E) (so arranged as to expose equal surfaces to the action of the beam) which communicate by flexible tubes (F G) of equal length, with the common hearing-tube (H). The receivers (D E) are placed upon slides, which can be moved along the graduated supports (I K). The beams of light passing through the interrupting disk (C) are alternately cut off by the swinging of a pendulum (L). Thus a musical tone is produced alternately from the substance in D and from that in E. One of the receivers is kept at a constant point upon its scale, and the other receiver is moved toward or from the focus of its beam until the ear decides that the sounds produced from D and E are of equal intensity. The relative positions of the receivers are then noted.

(2.) Another method of investigation is based upon the production of an interference of sound, and the apparatus employed is shown in fig. 11. The interrupter consists of a tuning-fork (A), which is kept in continuous vibration by means of an electro-magnet (B).

A powerful beam of light is brought to a focus between the prongs of the tuning-fork (A), and the passage of the beam is more or less obstructed by the vibration of the opaque screens (C D) carried by the prongs of the fork.

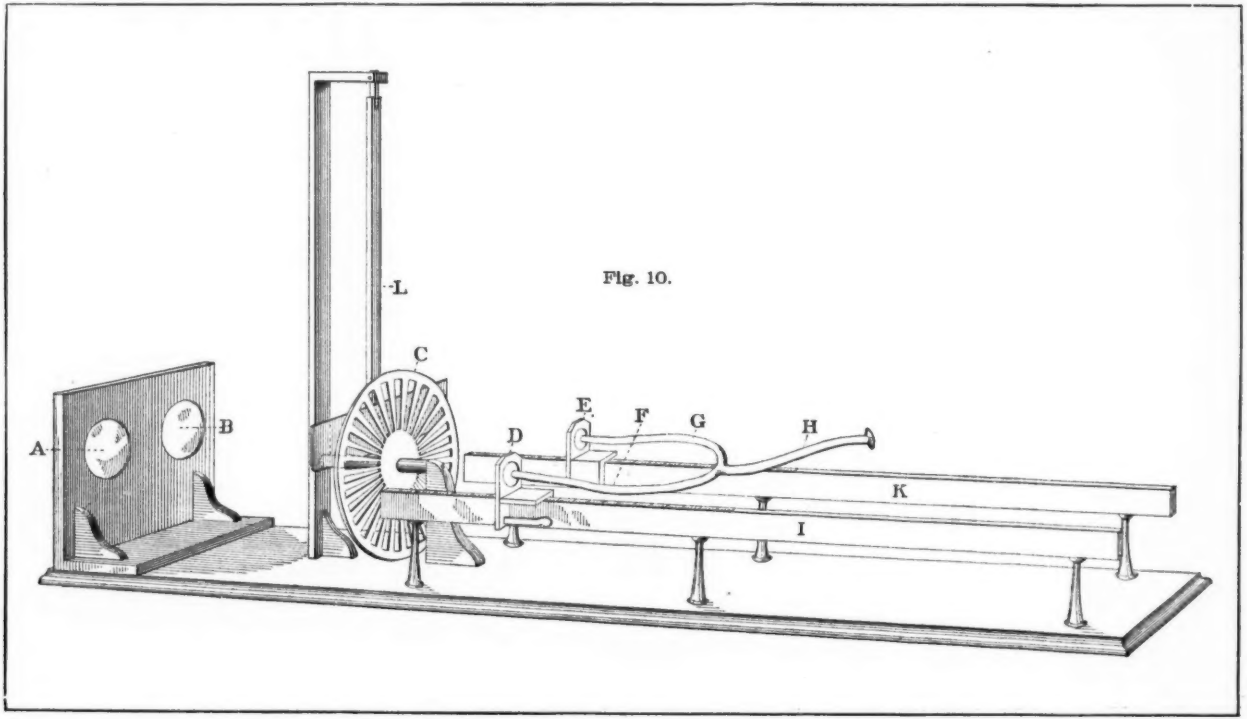


Fig. 10.

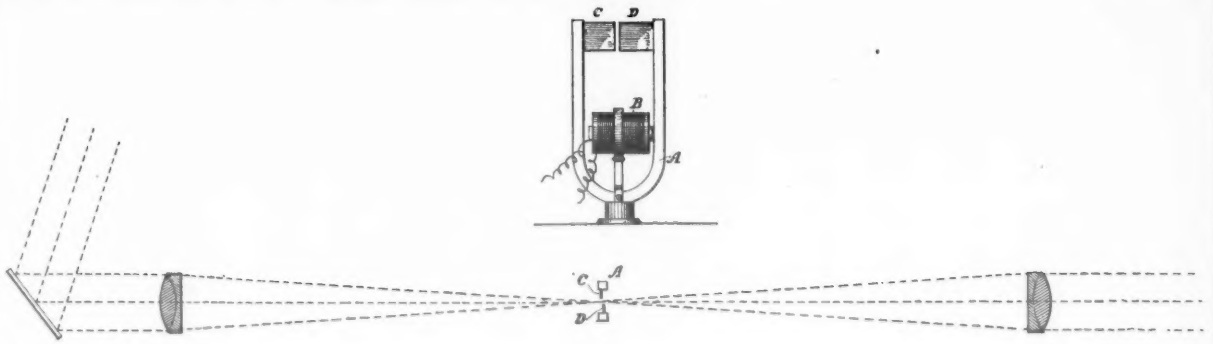
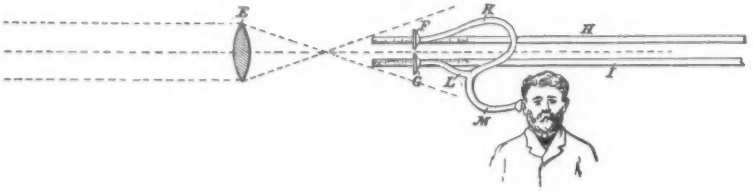


Fig. 11.



As the tuning-fork (A) produces a sound by its own vibration, it is placed at a sufficient distance away to be inaudible through the air, and a system of lenses is employed for the purpose of bringing the undulating beam of light to the receiving lens (E) with as little loss as possible. The two receivers (F G) are attached to slides which move upon the graduated supports (H I) on opposite sides of the axis of the beam, and the receivers are connected by flexible tubes of unequal length (K L) communicating with the common hearing-tube (M).

The length of the tube (K) is such that the sonorous vibrations from the receivers (F G) reach the common hearing-tube (M) in opposite phases. Under these circumstances silence is produced when the vibrations in the receiver (F G) are of equal intensity. When the intensities are unequal, a residual effect is perceived. In operating the instrument the position of the receiver (G) remains constant, and the receiver (F) is moved to or from the focus of the beam until complete silence is produced. The relative positions of the two receivers are then noted.

(3.) Another mode is as follows: The loudness of a musical tone produced by the action of light is compared with the loudness of a tone of similar pitch produced by electrical means. A rheostat introduced into the circuit enables us to measure the amount of resistance required to render the electrical sound equal in intensity to the other.

(4.) If the tuning-fork (A) in fig. 11 is thrown into vibration by an undulatory instead of an intermittent current passed through the electro-magnet, (B_1) it is probable that a musical tone, electrically produced in the receiver (F) by the action of the same current, would be found capable of extinguishing the effect produced in the receiver (G) by the action of the undulatory beam of light, in which case it should be possible to establish an acoustic balance between the effects produced by light and electricity by introducing sufficient resistance into the electric circuit.

Upon the nature of the rays that produce Sonorous effects in different substances.

In my paper read before the American Association last August and in the present paper I have used the word "light" in its usual rather than its scientific sense, and I have not hitherto attempted to discriminate the effects produced by the different constituents of ordinary light, the thermal, luminous, and actinic rays. I find, however, that the adoption of the word "photophone" by Mr. Tainter and myself has led to the assumption that we believed the audible effects discovered by us to be due entirely to the action of luminous rays. The

meaning we have uniformly attached to the words "photophone" and "light" will be obvious from the following passage, quoted from my Boston paper:

"Although effects are produced as above shown by forms of radiant energy, which are invisible, we have named the apparatus for the production and reproduction of sound in this way the 'photophone' *because an ordinary beam of light contains the rays which are operative.*"

To avoid in future any misunderstandings upon this point we have decided to adopt the term "*radiophone*," proposed by M. Mercadier, as a general term signifying an apparatus for the production of sound by any form of radiant energy, limiting the words *thermophone*, *photophone*, and *actinophone* to apparatus for the production of sound by thermal, luminous or actinic rays respectively.

M. Mercadier, in the course of his researches in radiophony, passed an intermittent beam from an electric lamp through a prism, and then examined the audible effects produced in different parts of the spectrum. (*Comptes Rendus*, Dec. 6th, 1880.)

We have repeated this experiment, using the sun as our source of radiation, and have obtained results somewhat different from those noted by M. Mercadier.

(1.) A beam of sunlight was reflected from a heliostat (A, fig. 12) through an achromatic lens (B), so as to form an image of the sun upon the slit (C).

The beam then passed through another achromatic lens (D) and through a bisulphide of carbon prism (E), forming a spectrum of great intensity, which, when focussed upon a screen, was found to be sufficiently pure to show the principal absorption lines of the solar spectrum.

The disk-interrupter (F) was then turned with sufficient rapidity to produce from five to six hundred interruptions of the light per second, and the spectrum was explored with the receiver (G), which was so arranged that the lamp-black surface exposed was limited by a slit, as shown.

Under these circumstances sounds were obtained in every part of the visible spectrum (excepting the extreme half of the violet), as well as in the ultra-red. A continuous increase in the loudness of the sound was observed upon moving the receiver (G) gradually from the violet into the ultra-red. The point of maximum sound lay very far out in the ultra-red. Beyond this point the sound began to decrease, and then stopped so suddenly that a very slight motion of the receiver (G) made all the difference between almost maximum sound and complete silence.*

*The results obtained in this and subsequent experiments are shown in a tabulated form in fig. 14.

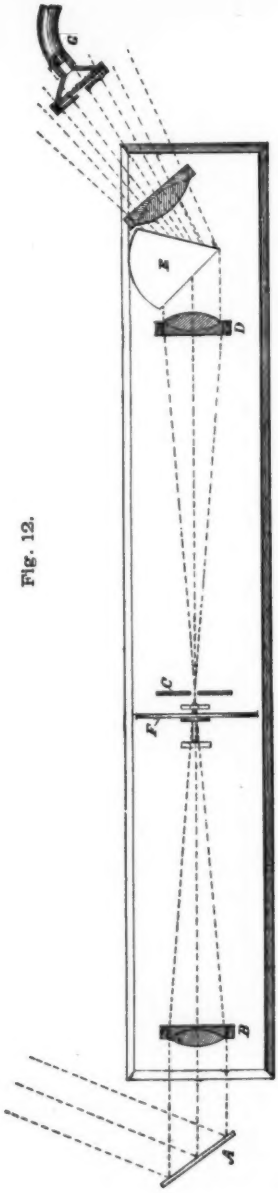


Fig. 12.

(2.) The lamp-blacked wire gauze was then removed and the interior of the receiver (G) was filled with red worsted. Upon exploring the spectrum as before, entirely different results were obtained. The maximum effect was produced in the green at that part where the red worsted appeared to be black. On either side of this point the sound gradually died away, becoming inaudible on the one side in the middle of the indigo, and on the other at a short distance outside the edge of the red.

(3.) Upon substituting green silk for red worsted the limits of audition appeared to be the middle of the blue and a point a short distance out in the ultra-red. Maximum in the red.

(4.) Some hard rubber shavings were now placed in the receiver (G). The limits of inaudibility appeared to be on the one hand the junction of the green and blue, and on the other the outside edge of the red. Maximum in the yellow. Mr. Tainter thought he could hear a little way into the ultra-red, and to his ear the maximum was about the junction of the red and orange.*

(5.) A test-tube containing the vapor of sulphuric ether was then substituted for the receiver (G). Commencing at the violet end, the test-tube was gradually moved down the spectrum and out into the ultra-red without audible effect, but when a certain point far out in the ultra-red was reached a distinct musical tone suddenly made its appearance, which disappeared as suddenly on moving the test-tube a very little further on.

(6.) Upon exploring the spectrum with a test-tube containing the vapor of iodine the limits of audibility appeared to be the middle of the red and the junction of the blue and indigo. Maximum in the green.

(7.) A test-tube containing peroxide of nitrogen was substituted for that containing iodine. Distinct sounds were obtained in all parts of the visible spectrum, but no sounds were observed in the ultra-red. The sounds were well marked in all parts of the violet, and I even fancied that the audible effect extended a little way into the ultra-violet, but of this I cannot be certain. Upon examining the absorption spectrum of peroxide of nitrogen it was at once observed that the maximum sound was produced in that part of the spectrum where the greatest number of absorption lines made their appearance.

(8.) The spectrum was now explored by a selenium cell, and the audible effects were observed by means of a telephone in the same galvanic circuit with the cell. The maximum effect was produced in the red about its junction with the orange. The audible effect extended a little way into the ultra-red on

* In the diagram fig. 14 a mean of these readings is shown.

the one hand and up as high as the middle of the violet on the other.

Although the experiments so far made can only be considered as preliminary to others of a more refined nature, I think we are warranted in concluding that *the nature of the rays that produce sonorous effects in different substances depends upon the nature of the substances that are exposed to the beam, and that the sounds are in every case due to those rays of the spectrum that are absorbed by the body.*

The Spectrophone.

Our experiments upon the range of audibility of different substances in the spectrum have led us to the construction of a new instrument for use in spectrum analysis, which was described and exhibited to the Philosophical Society of Washington last Saturday.* The eye-piece of a spectroscope is removed, and sensitive substances are placed in the focal point of the instrument behind an opaque diaphragm containing a slit. These substances are put in communication with the ear by means of a hearing-tube, and thus the instrument is converted into a veritable "spectrophone," like that shown in fig. 13.

Suppose we smoke the interior of our spectrophonic receiver, and fill the cavity with peroxide of nitrogen gas. We have then a combination that gives us good sounds in all parts of the spectrum (visible and invisible), except the ultra-violet. Now, pass a rapidly-interrupted beam of light through some substance whose absorption spectrum is to be investigated, and bands of sound and silence are observed upon exploring the spectrum, the silent positions corresponding to the absorption bands. Of course, the ear cannot for one moment compete with the eye in the examination of the visible part of the spectrum; but in the invisible part beyond the red, where the eye is useless, the ear is invaluable. In working in this region of the spectrum, lamp-black alone may be used in the spectrophonic receiver. Indeed, the sounds produced by this substance in the ultra-red are so well marked as to constitute our instrument a most reliable and convenient substitute for the thermo-pile. A few experiments that have been made may be interesting.

(1.) The interrupted beam was filtered through a saturated solution of alum.

Result: The range of audibility in the ultra-red was slightly reduced by the absorption of a narrow band of the rays of lowest refrangibility. The sounds in the visible part of the spectrum seemed to be unaffected.

* Proc. of Phil. Soc. of Washington, April 16, 1881.

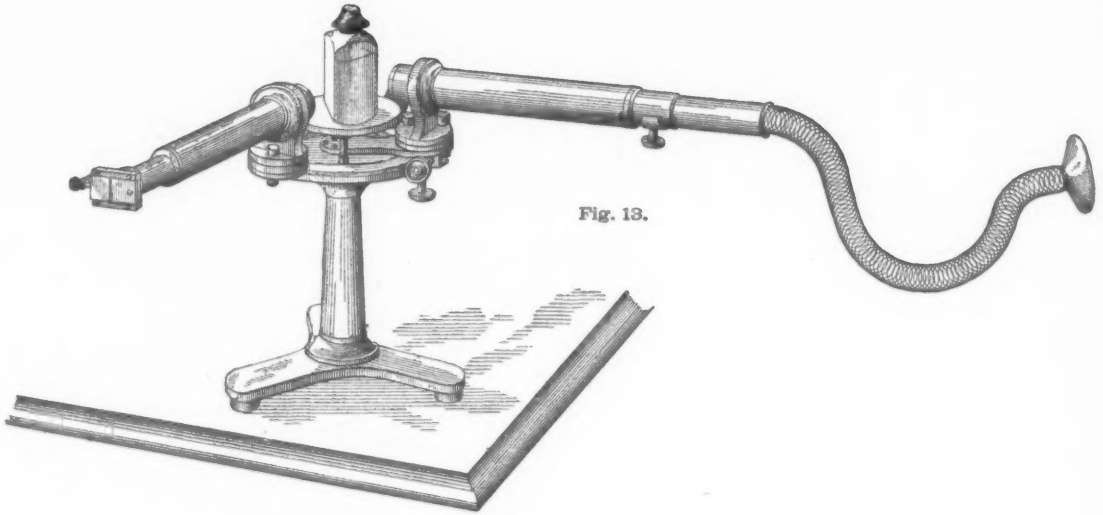
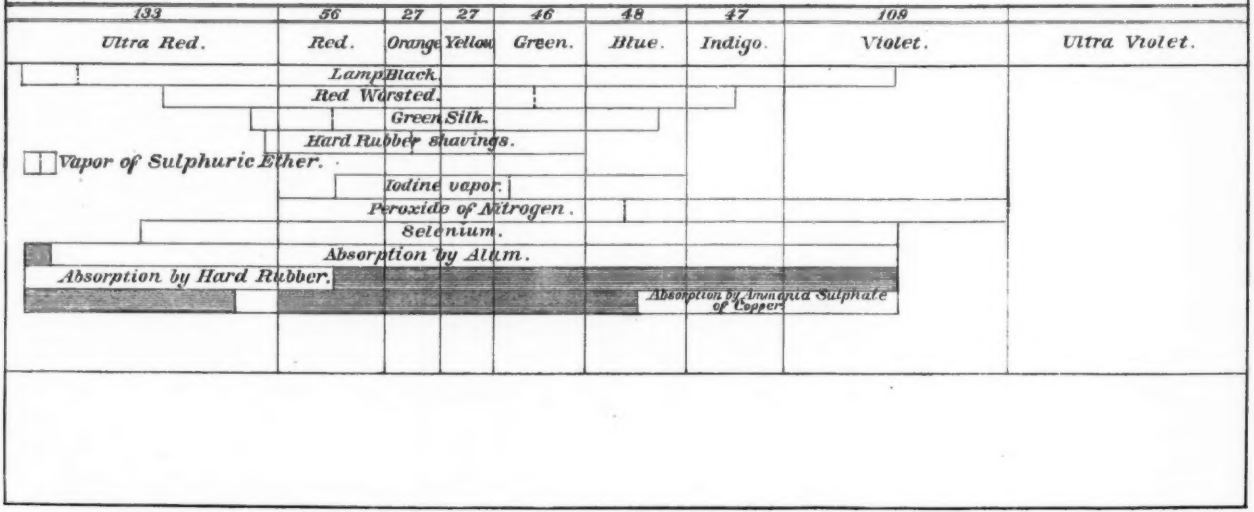


Fig. 13.

Fig. 14.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27
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Ultra Red.
Red.
Orange.
Yellow.
Green.
Blue.
Indigo.
Violet.
Ultra Violet.
Lamp Black.
Red Worsted.
Green Silk.
Hard Rubber Shavings.
Vapor of Sulphuric Ether.
Iodine vapor.
Peroxide of Nitrogen.
Selenium.
Absorption by Alum.
Absorption by Hard Rubber.
Absorption by Ammonia Sulphate of Copper.

(2.) A thin sheet of hard rubber was interposed in the path of the beam.

Result: Well-marked sounds in every part of the ultra-red. No sounds in the visible part of the spectrum, excepting the extreme half of the red.

These experiments reveal the cause of the curious fact alluded to in my paper read before the American Association last August—that sounds were heard from selenium when the beam was filtered through both hard rubber and alum at the same time. (See table of results in fig. 14).

(3.) A solution of ammonia-sulphate of copper was tried.

Result: When placed in the path of the beam the spectrum disappeared, with the exception of the blue and violet end. To the eye the spectrum was thus reduced to a single broad band of blue-violet light. To the ear, however, the spectrum revealed itself as two bands of sound with a broad space of silence between. The invisible rays transmitted constituted a narrow band just outside the red.

I think I have said enough to convince you of the value of this new method of examination, but I do not wish you to understand that we look upon our results as by any means complete. It is often more interesting to observe the first totterings of a child than to watch the firm tread of a full-grown man, and I feel that *our* first footsteps in this new field of science may have more of interest to you than the fuller results of mature research. This must be my excuse for having dwelt so long upon the details of incomplete experiments.

I recognize the fact that the spectrophone must ever remain a mere adjunct to the spectroscope, but I anticipate that it has a wide and independent field of usefulness in the investigation of absorption spectra in the ultra-red.

ART. LIX.—*The Solar Parallax as derived from the American Photographs of the Transit of Venus, 1874, December 8–9;* by D. P. TODD, M.A., Assistant in the Office of the American Ephemeris and Nautical Almanac.

HITHERTO no value of the solar parallax has been derived from the observations of the transit of Venus made at the American stations in 1874.

In the volume of observations recently issued, Part the First, *General Discussion of Results*, are given most of the data which are necessary for the derivation of the solar parallax from (1) the photographs of the transit, (2) the optic observations of the transit. We shall concern ourselves only with the photographic results: these are presented in pages 104–117, in very nearly the form of equations of condition involving the correction of the difference of right ascension of the sun and Venus, the correction of the difference of declination of the sun and Venus, and the correction of the assumed value of the solar parallax. The residual differences, (O.—C.), being given in distance, s, and in position-angle, p, every photograph furnishes two distinct equations of condition. The total number of photographs is two hundred and thirteen, distributed among the several stations as follows:—

THE NORTHERN STATIONS.		THE SOUTHERN STATIONS.	
Wladiwostok	13	Kerguelen	8
Nagasaki	45	Hobart Town	37
Peking	26	Campbelltown	32
		Queenstown	45
		Chatham Island	7

These equations cannot be regarded as definitive: in addition to the corrections for longitude of the stations (provisional values having been adopted in several cases), three small corrections arising from the absorption of the solar and the terrestrial atmospheres have still to be applied, whose general effect on the solar parallax has been considered immediately preceding the equations of condition themselves, pages 102–103. The first and the second effects being supposably small and acting contrariwise on the solar parallax, we may, without very great uncertainty, disregard their combined action. The third correction should be investigated independently from the equations of condition themselves; and this again cannot advantageously be done until the definitive longitudes have been obtained: all the effects of absorption of the solar and the terrestrial atmospheres may then be most opportunely considered.

The Equations of Condition in s.

Putting, then, $\delta\lambda_1$, $\delta\lambda_2 \ldots \delta\lambda_8$ equal to zero, every photograph gives one equation of condition in s of the form

$$0 = a\,\delta A + b\,\delta D + c\,\delta\varpi - (O.-C.)$$

The normal equations in s are as follow :—

$$\begin{aligned} &+ 23{\cdot}99\,\delta A + 24{\cdot}71\,\delta D - 28{\cdot}72\,\delta\varpi - 82{\cdot}17 = 0 \\ &+ 24{\cdot}71\,\delta A + 184{\cdot}46\,\delta D - 3{\cdot}16\,\delta\varpi - 439{\cdot}51 = 0 \\ &- 28{\cdot}72\,\delta A - 3{\cdot}16\,\delta D + 484{\cdot}51\,\delta\varpi + 21{\cdot}72 = 0 \end{aligned}$$

whose solution gives—

$$\begin{aligned} \delta A &= + 1''{\cdot}181 \pm 0''{\cdot}202 \\ \delta D &= + 2''{\cdot}225 \pm 0''{\cdot}070 \\ \delta\varpi &= + 0''{\cdot}0397 \pm 0''{\cdot}0418 \end{aligned}$$

The probable error of a single photograph is $0''{\cdot}88$.

The sums of the squares of the absolute terms in the equations of condition are as follow :—

$$\begin{aligned} [nn]_W &= 52''{\cdot}48 \\ [nn]_N &= 318{\cdot}25 \\ [nn]_P &= 130{\cdot}18 \end{aligned}$$

$$\begin{aligned} [nn]_K &= 37''{\cdot}02 \\ [nn]_H &= 115{\cdot}65 \\ [nn]_C &= 414{\cdot}46 \\ [nn]_Q &= 337{\cdot}63 \\ [nn]_{Ch} &= 27{\cdot}83 \\ [nn] &= 1433{\cdot}50 \end{aligned}$$

The sums of the squares of the outstanding residuals are as follow :—

$$\begin{aligned} [vv]_W &= 7''{\cdot}14 \\ [vv]_N &= 52{\cdot}47 \\ [vv]_P &= 29{\cdot}28 \end{aligned}$$

$$\begin{aligned} [vv]_K &= 20''{\cdot}44 \\ [vv]_H &= 59{\cdot}74 \\ [vv]_C &= 95{\cdot}16 \\ [vv]_Q &= 85{\cdot}67 \\ [vv]_{Ch} &= 8{\cdot}91 \\ [vv] &= 358{\cdot}81 \end{aligned}$$

The Equations of Condition in p.

Putting, as before, $\delta\lambda_1$, $\delta\lambda_2 \ldots \delta\lambda_8$ equal to zero, every photograph gives one equation of condition in p of the form

$$0 = a'\,\delta A + b'\,\delta D + c'\,\delta\varpi - (O.'-C.')$$

The normal equations in p are as follow :—

$$\begin{aligned} &+ 8682117\,\delta A - 1404261\,\delta D - 138999{\cdot}20\,\delta\varpi - 142109{\cdot}4 = 0 \\ &- 1404261\,\delta A + 1521370\,\delta D - 25093{\cdot}11\,\delta\varpi + 10442{\cdot}1 = 0 \\ &- 138999{\cdot}20\,\delta A - 25093{\cdot}11\,\delta D + 7326{\cdot}76\,\delta\varpi + 2651{\cdot}6 = 0 \end{aligned}$$

whose solution gives—

$$\begin{aligned} \delta A &= + 1''{\cdot}109 \pm 0''{\cdot}109 \\ \delta D &= + 0''{\cdot}637 \pm 0''{\cdot}224 \\ \delta\varpi &= + 0''{\cdot}0252 \pm 0''{\cdot}0595 \end{aligned}$$

The probable error of a single photograph is $3''{\cdot}447$.

The sums of the squares of the absolute terms in the equations of condition are as follow :—

$$[nn]_W = 358'{\cdot}65 \qquad [nn]_K = 381'{\cdot}20$$
$$[nn]_N = 1271{\cdot}49 \qquad [nn]_H = 1924{\cdot}85$$
$$[nn]_P = 269{\cdot}08 \qquad [nn]_C = 2044{\cdot}68$$
$$[nn]_Q = 1462{\cdot}97$$
$$[nn]_{Ch} = 220{\cdot}70$$
$$[nn] = 7933{\cdot}62$$

The sums of the squares of the outstanding residuals are as follow :—

$$[vv]_W = 323'{\cdot}65 \qquad [vv]_K = 174'{\cdot}34$$
$$[vv]_N = 972{\cdot}02 \qquad [vv]_H = 840{\cdot}69$$
$$[vv]_P = 519{\cdot}77 \qquad [vv]_C = 1236{\cdot}90$$
$$[vv]_Q = 1232{\cdot}09$$
$$[vv]_{Ch} = 176{\cdot}04$$
$$[vv] = 5475{\cdot}50$$

Final Values of δA, δD, $\delta\varpi$.

It seems likely that some of the probable errors of these quantities which have been derived are illusory. The best course, however, which we can now pursue will be to combine the values of δA, δD, and $\delta\varpi$ obtained from the two solutions in accordance with the weights depending upon these probable errors.

We thus have, for δA,

From solution in s, $\delta A = + 1''{\cdot}181 \pm 0''{\cdot}202$
From solution in p, $\delta A = + 1''{\cdot}109 \pm 0''{\cdot}109$
Final value, $\delta A = + 0^s{\cdot}075 \pm 0^s{\cdot}006$

And for δD,

From solution in s, $\delta D = + 2''{\cdot}225 \pm 0''{\cdot}070$
From solution in p, $\delta D = + 0''{\cdot}637 \pm 0''{\cdot}224$
Final value, $\delta D = + 2''{\cdot}083 \pm 0''{\cdot}067$

And for $\delta\varpi$,

From solution in s, $\delta\varpi = + 0''{\cdot}0397 \pm 0''{\cdot}0418$
From solution in p, $\delta\varpi = + 0''{\cdot}0252 \pm 0''{\cdot}0595$
Final value, $\delta\varpi = + 0''{\cdot}035 \pm 0''{\cdot}034$

The assumed value of ϖ being $8''{\cdot}848$, we have, finally, for the mean equatorial horizontal parallax of the sun,

$$8''{\cdot}883 \pm 0''{\cdot}034$$

corresponding (if we adopt the dimensions of the earth given by Colonel A. R. Clarke*) to a distance between the centres of the sun and earth equal to

148,103,000 kilometers = 92,028,000 miles.

Washington, April 27, 1881.

* Geodesy . . . Oxford, Clarendon Press, 1880, page 319.

ART. LX.—*On some remarkable Fossil Fishes from the Devonian Rocks of Scaumenac Bay, in the Province of Quebec;* by J. F. WHITEAVES.

IMMEDIATELY after my paper on the Canadian *Pterichthys** was written, Mr. A. H. Foord, of the Geological Survey of Canada, went down to the Baie des Chaleurs and spent two months and a half of the summer of 1880 in a careful and systematic examination of the fish-bearing beds of the Devonian rocks of the north bank of the mouth of the Restigouche River. The exact locality at which the *Pterichthys Canadensis* was found is not the Baie des Chaleurs proper but Scaumenac (sometimes written Escuminac) Bay, Restigouche Harbor, in the County of Bonaventure. On the shores of this bay a series of shales, sandstones and conglomerates, now known to be of Devonian age, are overlaid, apparently unconformably, by the red sandstones and conglomerates of the "Bonaventure Formation."

From these Devonian rocks Mr. Foord succeeded in obtaining a large and interesting collection of fossil fishes. Fully four-fifths of the entire number of specimens in this collection are referable to the genus *Pterichthys*, which, at this locality, seems to be represented by only one species, the *P. Canadensis*. Some of these are nearly perfect and want only the fins proper and the tail, while others are mere isolated plates or detached portions of the pectoral spines. One of the specimens shows that the Canadian *Pterichthys* had two labial appendages or barbels attached to the front margin of the head. These barbels are almost exactly similar in shape to those indicated by dotted lines in the ideal representation of the genus *Pterichthys* on Plate VI of the "Monographie des Poissons Fossiles du Vieux Grès Rouge," which Agassiz claims to have seen in his *P. latus*, but in *P. Canadensis* the barbels are very close together at their bases. In two other specimens of a *Pterichthys* collected by Mr. Foord, two remarkable, flattened conical, dermal processes are plainly visible on the helmet, one on each side of the orbital cavity. Posteriorly each process appears to fit into the angle formed by the junction of the prelateral with the nuchal and post-lateral plates, while anteriorly they are each directed obliquely outward and forward across the prelaterals, which they partly cover. In one of the specimens the dermal processes, which are ornamented with a sculpture precisely similar to that of all the other plates, are half an inch long and two lines and a half broad near their base. They taper gradually from their base to an obtuse point and are pressed close to the surface of the helmet.

In addition to these remains of *Pterichthys*, there are examples of eight or nine species of fossil fishes in Mr. Foord's collection, which belong to at least seven genera. The following is a brief description of the most striking characters of six of these species,

* On a new species of *Pterichthys*, allied to *Bothriolepis ornata* Eichwald, etc., this Journal, xx, 132, August, 1880.

the affinities of the remainder not having yet been satisfactorily ascertained:

Diplacanthus.

Two specimens, one showing scales and longitudinally grooved fin spines and the other a large portion of the body, of a small, smooth-scaled *Diplacanthus*, very like the *D. striatus* of Agassiz and possibly identical with that species.

Phaneropleuron curtum, sp. nov.

Four crushed and distorted but nearly perfect examples and several fragments of a new species of *Phaneropleuron*, which differs from the *P. Andersoni* of Huxley, from the Old Red Sandstone of Dura Den, in its smaller size and in its much greater height or depth as compared with its length. *P. Andersoni* is represented as being about five and a half times as long as high, whereas in the largest specimen of *P. curtum* yet collected, which is six inches long, the length is not much more than twice the height.

Eusthenopteron Foordi, nov. gen. et sp.

The name *Eusthenopteron** is proposed for a supposed new genus which resembles the *Tristichopterus* of Sir Philip Egerton in the shape and ornamentation of its scales and cranial plates, in the circumstance that the fin rays of its anal and second dorsal fins are both supported by three osselets articulated to a broad interspinous apophysis, and in some other important particulars. But the vertebral centers of *Tristichopterus* are said to be ossified, and the osselets which support the rays of the lower lobe of the tail are described as "springing from eight or nine interspinous bones," whereas in *Eusthenopteron* the vertebral centers are not ossified and the caudal osselets are articulated to the modified hœmal spines. In *Eusthenoptheron*, too, the osselets and interspinous bones of the anal and second dorsal are larger than those of *Tristichopterus*, and different also in their shape and relative proportions.

The species, which is named after its discoverer, Mr. A. H. Foord, may be recognized by its large size (it appears to have attained to a length of two feet or more) and by its narrowly elongated and acutely pointed first dorsal fin.

Glyptolepis microlepidotus Agassiz.

A single, nearly perfect specimen of a small-scaled *Glyptolepis* which cannot at present be distinguished from the above named European species.

Glyptolepis ——.

A second species of *Glyptolepis*, apparently allied to the *G. leptopterus* of Agassiz, is indicated by a number of large detached scales, nearly an inch in diameter, which are associated with slender rib-bones, an operculum and a fragment of a jaw with teeth, on the same small slabs of shale.

* From *εὐ-σθενης*, stout, and *πτερον*, a fin.

Cheirolepis Canadensis, nov. sp.

Four exquisitely preserved specimens, two of which are nearly perfect, of a large *Cheirolepis* which resembles the *C. macrocephalus* of McCoy and the *C. Cumingiæ* of Agassiz in the size, contour and sculpture of the scales of the body and fins, but which seems to differ from both in the relative position of its fins. In *C. Canadensis* the ventrals are separated from the pectorals by a short interval and from the anal by a much longer one. In *C. macrocephalus*, on the other hand, the ventrals are represented by McCoy as being nearer to the anal than they are to the pectorals, while in *C. Cumingiæ*, according to Hugh Miller, "the large pectorals almost encroach on the ventrals and the ventrals on the anal fin."

A more detailed description of these species will be found in the current number of the "Canadian Naturalist."*

The existence of fossil plants as well as of fish remains in the Devonian shales and sandstones of Scaumenac Bay was noticed by Dr. Abraham Gesner in 1842, and from these rocks Mr. Foord also obtained four species of ferns, which have recently been reported on by Principal Dawson.

The analogies between the fossil fauna of the fish-bearing beds of Scaumenac Bay and that of the Old Red Sandstone of Scotland and Russia are very striking. The *Pterichthys Canadensis* is still doubtfully distinct from the *Bothriolepis ornata* of Europe; the fragments of a *Diplacanthus* obtained by Mr. Foord have apparently much the same characters as the *D. striatus* of Agassiz, and the genus *Phaneropleuron* can now be shown to occur in the Devonian rocks of Canada as well as in those of Scotland. *Eusthenopteron* has many features in common with *Tristichopterus;* one species of *Glyptolepis* from Scaumenac Bay seems to be identical with the *G. microlepidotus* of Agassiz, from Lethen Bar, while the other bears a general resemblance to the *G. leptopterus* of the same author; and lastly, *Cheirolepis Canadensis* is certainly very closely allied to two Scotch species.

These Devonian rocks at Scaumenac may have been of freshwater or estuarine origin, for no traces of any marine invertebrata have yet been detected in any of them and the fossil fishes which they contain are invariably found associated with land plants.

Montreal, April 7th, 1881.

ART. LXI.—*On the Rain-Fall in Wallingford, Connecticut, between* 1856 *and* 1881; Record kept by B. F. HARRISON.

THE following table gives the amount in inches of rain and melted snow for each month of each year. The depth of snow in the winter months is also given. The record extends from April, 1856 to December, 1880, inclusive, with, however, the exception

* Vol. x, new series.

of the five closing months of 1862, and the years 1863, 1864. At the close the means for each month are given, and also the final average for the whole period over which the observations extend.

	1856.		1857.		1858.		1859.		1860.		1861.	
	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.	Rain.	Snow.
January	....	....	4·39	27·70	3·13	4·00	6·94	31·00	2·38	11·60	4·07	20·00
Febru'y	....	....	2·08	2·75	1·92	5·00	4·24	13·00	3·13	17·50	2·90	....
March	....	....	2·47	10·00	1·57	13·50	8·45	6·00	2·62	·50	5·02	27·00
April	4·10	....	7·11	....	3·87	....	3·76	....	2·11	·50	5·83	9·00
May	6·85	....	7·76	....	2·62	....	4·73	....	4·04	....	5·67	....
June	3·07	....	3·23	....	5·08	....	6·25	....	1·90	....	3·68	....
July	2·93	....	8·29	....	3·26	....	2·58	....	2·72	....	2·85	....
August	11·68	....	5·62	....	4·02	....	6·12	....	5·53	....	5·66	....
Septem.	3·22	....	3·17	....	5·18	....	5·63	....	3·38	....	4·61	....
October	1·98	....	5·88	....	3·29	....	1·91	....	3·10	....	2·40	....
Novem.	2·67	2·50	2·06	....	2·23	13·00	2·49	....	6·37	....	4·47	4·00
Decem'r	6·61	12·50	5·79	5·90	4·47	3·00	4·01	5·50	4·97	10·50	1·77	....
Total	43·11	15·00	57·85	46·35	41·64	38·50	57.11	55·50	42·25	40·60	48·93	60·00

	1862.		1865.		1866.		1867.		1868.		1869.	
January	5·71	16·00	4·92	11·50	1·71	14·50	2·42	26·00	4·55	27·00	3·05	5·00
Febru'y	3·01	19·00	4·60	2·90	6·48	5·00	2·64	20·00	1·69	12·00	5·22	13·00
March	4·30	4·00	6·31	....	3·41	3·00	4·08	16·00	2·66	15·00	7·02	13·00
April	1·93	....	3·26	....	2·89	....	2·76	....	5·58	15·00	2·16	....
May	2·93	....	7·26	....	5·80	....	6·31	....	7·79	....	6·36	....
June	7·60	....	4·89	....	4·31	....	5·40	....	3·67	....	3·23	....
July	5·28	....	6·84	....	3·28	....	2·45	....	2·44	....	2·98	....
August	....	....	1·57	....	4·21	....	10·53	....	7·27	....	1·95	....
Septem.	....	....	1·38	....	6·17	....	2·59	....	8·40	....	3·27	....
October	....	....	4·33	....	3·35	....	5·91	....	·93	....	13·29	....
Novem.	....	....	3·15	....	4·96	....	3·50	6·00	4·31	....	3·58	2·00
Decem'r	....	....	4·01	19·00	4·38	10·50	2·70	13·00	2·47	12·00	6·35	15·00
Total	30·76	39·00	52·52	23·50	50·95	33·00	51·29	81·00	51·76	81·00	58·46	48·00

	1870.		1871.		1872.		1873.		1874.		1875.	
January	6·38	6·00	3·88	24·00	1·47	2·00	6·71	17·00	6·51	17·00	2·90	11·00
Febru'y	5·19	16·00	3·99	22·00	2·99	12·50	3·52	13·00	3·88	26·00	5·18	8·50
March	5·60	19·00	6·54	....	4·16	7·00	2·50	2·00	1·53	6·00	5·48	29·50
April	6·21	....	3·84	4·00	1·72	1·00	3·28	1.00	7·88	7·00	3·74	18·50
May	1·39	....	4·37	....	3·60	....	5·42	....	3·78	....	2·12	....
June	3·12	....	6·27	....	4·23	....	·38	....	1·93	....	3·37	....
July	2·96	....	2·03	....	5·02	....	2·17	....	4·54	....	3·21	....
August	2·11	....	7·04	....	6·96	....	9·93	....	7·13	....	4·88	....
Septem.	1·40	....	2·02	....	4·31	....	2·16	....	3·29	....	2·10	....
October	5·37	....	5·55	....	2·70	....	5·03	....	1·20	....	3·32	....
Novem.	3·43	....	4·62	·50	5·38	10·50	4·36	4·00	3·12	·50	5·72	....
Decem'r	2·19	7·00	3·23	13·50	3·66	33·50	4·84	20·00	2·32	10·00	1·37	3·50
Total	45·35	48·00	53·38	64·00	46·20	66·50	50·30	57 00	47·11	66·50	43·39	71·00

	1876.		1877.		1878.		1879.		1880.	
January	1·36	3·00	3·47	18·00	5·83	5·50	2·64	20·50	4·02	5·00
Febru'y	5·26	13·00	1·50	2·50	5.71	9·00	3·88	11·50	3·79	8·50
March	10·90	5·00	8·30	5·00	2·95	....	4·93	10·50	3·63	10·00
April	4·98	....	2·35	....	4·73	....	5·80	....	4·59	....
May	3·61	....	1·07	....	3·44	....	2·32	....	1·16	....
June	1·40	....	6·59	....	3·97	....	3·90	....	2·04	....
July	10·01	....	2·35	....	3·40	....	8·99	....	5·38	....
August	1·69	....	4·63	....	3·96	....	8·04	....	4·62	....
Septem.	5·00	....	·65	....	4·87	....	1·80	....	3·86	....
October	1·43	1·00	8·34	....	2·73	....	1·30	....	3·89	....
Novem.	4·37	1·50	6·81	....	5·87	·50	2·00	1·50	2·87	1·00
Decem'r	4·19	24·50	1·76	....	7·06	7·00	4·19	7·50	3·00	16·50
Total	54·20	48·00	47·82	25·50	54·52	22·00	49·79	51·50	42·85	41·00

FINAL AVERAGES.

	Total rain-fall for each month.	Monthly Average.	Total fall of snow for each month.	Monthly Average.
January	88·44	4·020	307·30	14·66
February	82·40	3.745	232·75	11·08
March	95·03	4·318	134·50	6·41
April	94·46	4·107	56·00	2·66
May	100·40	4·365	....	....
June	92·51	4·020	....	....
July	85·96	3·739	....	....
August	126·15	5·734	....	....
September	78·46	3·566	....	....
October	87·22	3·963	1·00	·05
November	89·44	4·065	34·50	·16
December	85·34	3·880	228·40	10·87

Total rain-fall for 22 years and 4 months.....1,105·81 inches.
Average annual rain-fall (including melted snow) 49·52
Total fall of snow..... 994·45
Average annual fall of snow..... 45·89

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Direct Synthesis of Ammonia.*—While passing nitrogen gas over freshly hydrogenized copper at a red heat, JOHNSON observed the formation of traces of ammonia. He therefore repeated his experiments and passed a mixture of pure nitrogen—evolved from ammonium nitrite—and hydrogen over spongy platinum at a low red heat. The hydrogen was produced first and then passed through silver nitrate and oil of vitriol, over pumice moistened with sulphuric acid, through Nessler's reagent and then over the spongy platinum. After the platinum had been heated to redness in the hydrogen and the absence of ammonia proved, the nitrogen was evolved and passed through the purify-

ing and drying apparatus with the hydrogen. When the mixture reached the hot platinum, ammonia was produced, the Nessler test became brown, the well known odor was perceived, red litmus was turned blue and white fumes were produced with hydrochloric acid. Quantitative experiments showed the production of 5·9 mgrms. NH_3 per hour in this apparatus. This result having been objected to on the ground that the vapor of some salt of ammonia might be carried by the rapid stream of gas through the solutions and be dissociated in the hot platinum, the author has made further experiments on the question. Hydrogen was passed through the apparatus till free from ammonia, and after the platinum was cold, nitrogen was passed through for the purpose of displacing the hydrogen; so that on subsequent heating in pure nitrogen the ammonia salt if present might be dissociated and yield its ammonia. But on admitting the nitrogen to the cold platinum, ammonia was produced, 24 mgrms. in an hour. The experiment was then repeated with nitrogen obtained by passing air over heated copper; but no ammonia appeared. Nor was any produced when the nitrogen prepared from the nitrite was previously passed over heated copper. Two hypotheses suggested themselves: either the heat rendered the nitrogen inactive, or some nitrogen oxide, which was present and yielded the ammonia, was removed by the hot copper. On examination it appeared that the nitrogen prepared from ammonium nitrite always contains some nitric oxide. To remove this, the nitrogen was passed through ferrous sulphate; and to test its purity it was then passed through a tared tube containing freshly-reduced copper heated to redness, the tube being weighed every hour. When the gas passed over a sufficient length of the ferrous sulphate solution, no increase in weight was observed in the copper tube. The nitrogen being now free from oxides, was used with hydrogen as before; and with cold spongy platinum, 3 mgrms. of ammonia was produced in an hour. But when the mixture of gases was passed over heated asbestus before reaching the platinum, though traces of ammonia were produced in the asbestus, none whatever appeared in the platinum until the asbestus tube had so far cooled as to be handled. Hence, it appears that the formation of ammonia is arrested by passing the nitrogen through a red-hot tube; and the author thinks this evidence strong that nitrogen, like phosphorus, exists in an active and an inactive state, the latter produced by heat.—*J. Chem. Soc.*, xxxix, 128, 130, March, 1881. G. F. B.

2. *On Blood-crystals and their Coloring Matter.*—Struve has observed that freshly prepared blood-crystals, after being rendered insoluble by the action of alcohol, their form remaining unchanged, may be completely decolorized by treatment with alcoholic ammonia. Glacial acetic acid causes them to swell, and extracts the color. When it evaporates they shrink, becoming irregular in form, but reassume their original size and shape on adding more acid. Concentrated sulphuric acid acts similarly on

the crystals but decomposes the coloring matter, removing the iron, and producing hematoporphyrin having a distinct absorption spectrum. The author therefore concludes that the blood crystals are really crystals of globulin mechanically mixed with the coloring matter, a view originally held by Reichert in 1847.—*Ber. Berl. Chem. Ges.*, xiv, 930, Apr., 1881. G. F. B.

3. *On the Absorption Spectra of Colorless Liquids.*—Russell and Lapraik have repeated and extended their observations of last summer on the absorption bands in the spectra of liquids ordinarily considered colorless. The spectra were in all cases observed with the eye, the spectroscope used being made by Desaga and having a single prism of heavy glass. The sources of light were a large Argand gas burner and the lime cylinder. Before reaching the slit, the light traversed a column of the liquid from 2 to 8 feet long. A plate is given showing the bands in the spectra of thirty-four liquids. Water, in a tube 6 feet in length gives a distinct absorption band between the 600 and 610 divisions of the scale, these divisions corresponding to millionths of a millimeter. It is darker on the more refrangible side and ends sharply, fading off gradually on the other side. The general absorption extends to about 665 in the red, and there appears to be a second band at 705–723. These bands are unaffected by temperature and also by salts in solution. Ordinary alcohol (in which absorption bands were first recognized) gives a band at 630. Methyl, propyl and amyl alcohols also give bands, the band being nearer the red the higher the alcohol in the series. The saline ethers show a band slightly nearer the blue end. Ethyl iodide gives a second band from 716 to 724. Amyl nitrate, acetate and iodide give bands like that of amyl alcohol, but a trifle nearer the blue. Amylene gives a band coincident with that of the saline ethers. The existence of the same band in all these amyl compounds shows its independence of the acid radical. Chloroform shows a faint band from 607 to 616, and a dark and sharp one from 711 to 717. Ethyl oxide gives the characteristic ethyl bands. Aldehyde and acetic acid show a large absorption at the red and a faint band, that of the latter body being the more refrangible. Benzene, in an 8-feet column, shows two bands, one from 606 to 616 and the other from 703 to 714, both remarkably sharp and dark. Methyl-benzene (toluene) shows the same bands but the former has become fainter while the latter is as dark as before. Xylene shows the same process continued farther. Mono- and di-chlorbenzene, the latter dissolved in ether, give the same bands, but the 606 band is fainter than in benzene. Napthalene fused gave three bands, two agreeing exactly with the benzene bands and the third with the general absorption of this body. Two feet of naphthalene produced as much absorption as six or eight times as much benzene; and benzene in its turn is more powerful as an absorber than either toluene or xylene. Phenol gives two bands, one agreeing nearly with the water band, the other from 679 to 710. Ammonia in aqueous solution shows five bands; the darkest is from 649 to 654;

two others coincide nearly, the one with the water, the other with the alcohol band; another narrow and sharp from 566 to 570; and a fifth from 698 to 708, clouded by the general absorption. In alcohol and ether changes were visible due probably to the less solubility of ammonia in these menstrua. Methylamine shows a fading out of the more refrangible bands and a strengthening of the 649 band. Ethylamine, di-ethylamine and triethylamine showed the effect of progressively replacing hydrogen by the alcohol radical. Aniline, toluidine and dimethylaniline, and also turpentine were examined. The only liquids which did not show bands were carbon disulphide and tetrachloride.—*J. Chem. Soc.*, xxxix, 168, April, 1881. G. F. B.

4. *On the supposed "Polarization of Sound."*—Professor S. W. Robinson has recently described a series of experiments intended to show the effect upon a sound wave of repeated reflections from a membranous medium placed at a given angle to the line of propagation. An L-shaped tube, one inch in diameter and three inches in length, was constructed of tin, the two branches meeting at an obtuse angle. The convex portion of the joint was replaced by a membrane gummed to the tube. This membrane was so placed that the normal to it made with the axes of the inclined branches of the tube angles each equal to the polarizing angle of incidence; this angle was so taken, after the methods of optics, that its tangent was equal to the ratio of velocities of propagation for the gas within (coal gas, $v=1420$), and that without (air, $v=1125$). A series of these L-tubes were connected together, and so arranged that the membranes were either all parallel, or, by a turn of half the system in a central joint, the two parts ("analyzer" and "polarizer") could be made perpendicular to each other. The openings at the two extremities were closed by membranes at right angles to the tubes. It was now expected that the sound impulse received at one extremity would be propagated through the tube, and at each of the joints covered with membranes there would be both reflection onward and refraction into the outside medium, and this would be shown by the effect at the other end. In the experiments the tube was filled by coal gas coming in near one end and having an exit, by a jet, at the other, where it was ignited; this was adopted to insure a constant pressure. No clear effect was observed when a simple sound was made before the first membrane, and hence an impulse, analogous to a simple sound wave, was obtained by the blow of a small ivory ball on the first membrane. This was suspended by a thread in front of the membrane, and was so arranged that it could be dropped through a given height against it; a second ball of glass, similarly suspended, rested lightly against the other terminal membrane, and the distance to which it was thrown by the impulse propagated through the tube was noted by a scale. The first ball was dropped several times at intervals of ten seconds, and each corresponding deflection of the other ball noted; then one half of the system was turned 90° in the central joint, as

above described, and the effect again noted; then a further turn of 90° was made, and so on. Several series of experiments were carried on: in one series of eighty trials the mean deflection when the membranes of the two halves of the tube were parallel was 6·47, and when perpendicular to each other 5·43, a diminution of intensity corresponding to 16·1 per cent; in another series the results were 1·68 and 1·04, corresponding to a diminution of 38·1 per cent. When the tubes were filled with air no deflection was observed.

The author concludes that by the repeated reflections from the surfaces of the membranes separating the coal gas and air a diminution in intensity is produced according to the relative positions of the membranes, analogous to the effects produced in the case of light by repeated reflections from a series of glass plates. From this he concludes that sound vibrations undergo true polarization also. In regard to this it may be said that while the method of experiment is ingenious and the results possess considerable interest, the subject seems to demand further experiment before conclusions can be safely drawn. The individual trials, while not agreeing very closely, certainly point to a marked difference between the parallel and perpendicular positions of the two sets of reflecting surfaces, but it seems probable that this may be explained by some peculiarity in the mechanical construction of the apparatus.

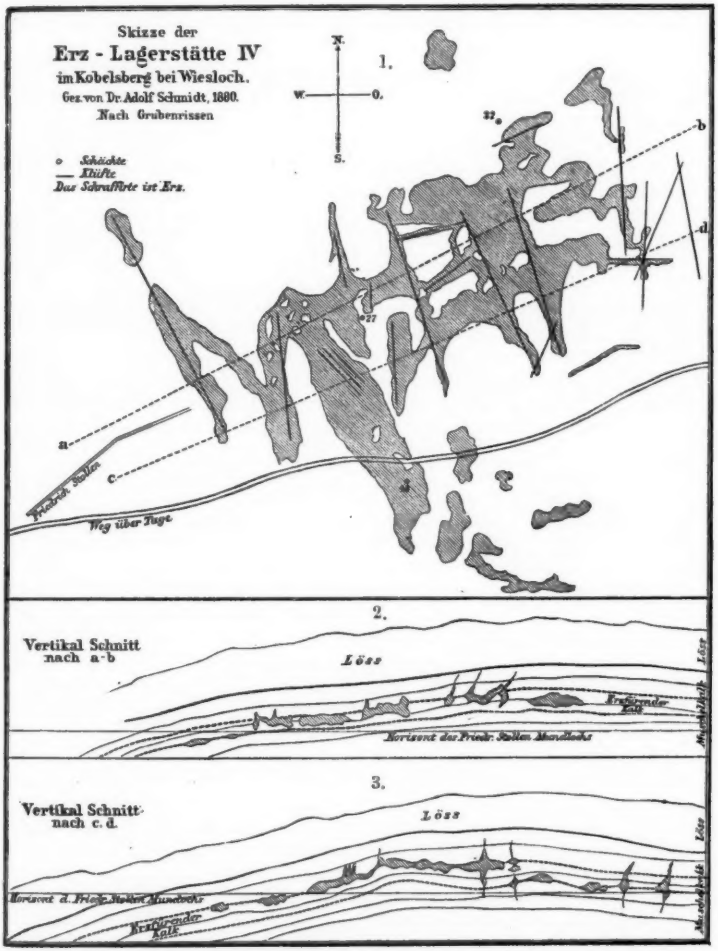
Assuming the polarization of the longitudinal vibrations of sound to have been absolutely demonstrated, the author goes further and draws conclusions, which are far too sweeping considering the nature of the premises—namely: that all vibrations in extended media, as light, are only longitudinal, and that when polarization takes place the vibrations become transversal.—*Journ. Frank. Institute*, 1881.

II. Geology and Natural History.

1. *The Zinc-ore Deposits of Wiesloch in Baden;* by Dr. Adolf Schmidt.* 122 pp. 8vo, with 3 plates. Heidelberg, 1881. (Carl Winter).—The deposits of zinc-ore, described by Dr. Schmidt, are situated near the village of Wiesloch, Baden, about 7½ miles south of Heidelberg. The "Buntsandstein" which has a considerable development at Heidelberg, dips gently to the south, and near Nussloch it disappears from the surface and the overlying "Muschelkalk" takes its place; this forms the rock in which the zinc deposits occur. The zinc is found as the sulphide, sphalerite or zinc blende, the carbonate, smithsonite, with hydrozincite in limited quantities. The sphalerite, which is mined only over a limited area, is regarded as the oldest deposit; it is, much of it, in the form of shell blende ("Schalenblende,") consisting of thin wavy layers of cryptocrystalline blende of different colors, and often alternating with galenite or marcasite; much of it is

* Die Zinkerz-lagerstätten von Wiesloch, Baden, von Dr. A. Schmidt.

stalactitic in form. Ordinary sphalerite with distinctly crystalline structure also occurs. The zinc carbonate, which forms the mass of the ore, occurs sometimes distinctly crystallized; also in the vitreous form called "zinkglas," the granular massive form, and finally in pseudomorphous deposits after other minerals and after various fossil shells. Of these the granular mineral, "Galmei," has the greatest economic importance.



Sketch of the ore-deposits at the Kobelsberg near Wiesloch, Baden. Scale, 1 : 2500. Figure 1, general sketch Figure 2, vertical section taken along the line *ab* (fig. 1). Figure 3, vertical section taken along the line *cd* (fig. 1).

Five independent deposits of ore have been worked in this region. These are irregular masses of ore, some five to seven meters in thickness, but with a considerable horizontal extent and with the greatest development in a north and south direction. The smallest deposit is about 140 meters long and 70 broad; and the dimensions of the largest are 600 and 300 meters. When examined more closely, each of these deposits is found to consist not of an uninterrupted and solid body of ore, but rather of a large number of small bodies, more or less continuous, enclosing masses of limestone. Figure 1 gives a ground sketch of one of the five ore deposits mentioned, and shows the peculiar lenticular forms of the ore masses (here the carbonate.) In general they extend in a northwesterly and southeasterly direction, and are joined together in an irregular way, as exhibited in the plate. Figures 2 and 3 represent two cross-sections, the first taken along the line *ab*, in figure 1, and the second along *cd;* these show still more clearly the form and distribution of the zinc ore in the enclosing limestone. The single masses have a maximum thickness of five meters, a varying breadth from 1 to 12 meters, and length from 10 to 100 meters. The ore masses are mostly confined to the layer of limestone called the ore-bearing bed ("Erzführender Kalk"), and follows generally its upper border passing only to a limited extent into the rock above; in some cases they pass suddenly from this upper line to the lower and extend along this—(figure 3). In all cases the ore takes the place of the limestone, showing that the ore deposit was preceded by the removal of the limestone.

These separate lenticular masses consist of the carbonate with more or less red clay, intermixed in some cases, the latter being in excess. The firmest and richest ore is found at the bottom, and consists of thin, wavy layers which can often be separated from one another, although, as a whole, it is massive and nearly pure. Above this nearly solid ore comes a middle portion made up of interlacing lines or threads of the pure ore with the space between, in part or wholly filled by masses of clay or loam. Finally the upper portion consists almost exclusively of clay with very thin and irregular threads of ore, and with numerous concretionary masses from the size of a hazelnut to the finest of particles, intimately intermingled with the clay. In most cases the ore is easily separated from the sides of the enclosing rock, though not infrequently the carbonate is firmly bound to the limestone and passes gradually into it; in such cases it is common to find the fossil shells changed into the zinc carbonate, and here, evidently, the mineral has arisen not by direct deposit but by a process of alteration of the limestone.

In regard to the origin of these deposits of zinc ore the conclusion is reached that they have been made in most cases by the direct filling of previously made cavities and cracks in the limestone, although in some cases the deposit of the zinc and the removal of the limestone must have gone on together. The form-

ing of the larger of the cavities is to be referred to the horizontal movement which resulted in the elevation of the Odenwald, and took place in connection with the formation of the Rhine valley. The original ores were the sulphides (sphalerite, marcasite and galenite), deposited from aqueous solutions infiltrating from above, as is proved by the existence of stalactites. The zinc carbonate which, as stated, forms the greater part of the ore taken out, must have been formed mostly from the oxidation of the zinc sulphide. This process of alteration was probably due originally to the action of the decomposition products of the marcasite which was deposited with the sphalerite, leading first to the formation of the zinc sulphate; and then from this there followed, with the calcium carbonate, the formation of the zinc carbonate and gypsum. This change of zinc carbonate is a process which can be successfully imitated in the laboratory. In addition to the carbonate which has been thus formed from the alteration of the zinc sulphide there is also to be recognized that which has resulted from the alteration of limestone, and by direct deposit from solution.

Dr. Schmidt's memoir, from which the above facts and accompanying plate have been taken, is of great interest both to the theoretical and mining geologist. It is in some respects a continuation of the valuable work by the same author on the lead mines of Missouri, published in 1874 in connection with the Report on the Geological Survey of Missouri, and noticed in vol. x, 1875, of this Journal.

2. *Geological Map of the United States*, compiled by C. H. Hitchcock; issued both in sheets and on rollers. New York, 1881. With an explanatory pamphlet in large 8vo of 30 pages. (Published by J. Bien). — This colored geological map of the United States has a breadth of thirteen feet and a length of eight. "It is made for a wall map," and apparently chiefly to serve the purpose of the lecturer, the details being few and the style of work coarse compared with what we find on foreign geological maps of like size. The formations distinguished embrace three divisions under the Tertiary; the Laramie, Cretaceous and Jura-Trias under the Mesozoic; three under the Carboniferous; one for the Devonian; three for the Silurian, the lower being the Cambrian or Primordial; and *four* for the Metamorphic rocks, namely, the Huronian, the gneiss of the Atlantic slope "including the Montalban and metamorphic Paleozoic," the Labrador or Norian, and the Laurentian. The compiler has sought assistance from all available sources, and has endeavored to give the latest and best results. Great difficulties have come as regards the western portion from the incompleteness of the geological surveys of the regions, and some parts might well have been left uncolored.

Professor Hitchcock has naturally introduced his own views of New England geology, on part of which the writer has found occasion, through his extended surveys, to differ from him. The sentence, "if orography is determined by stratigraphy, then the

gneisses of New England are mainly of pre-Silurian age," would, according to the writer's observations, be more nearly correct if a *not* were introduced before the word *mainly*. It appears to the writer, further, that if all the pre-Cambrian (=pre-Primordial =Archæan) areas had received one color, and, at the same time, such metamorphic rocks as are not known by stratigraphical evidence to belong to this division, or to any of those higher in the series, had been left without color, the map would have been more satisfactory. The Huronian cannot be told by lithological tests, and the Huronian areas, so made, that have any other basis than a lithological are very limited, and would have been sufficiently distinguished by lining.

But the metamorphic areas are only a very small part of the formations represented. The chart also gives the outlines, more or less well ascertained, of the areas of eruptive rocks in the west; the southern limit of Glacier phenomena east of the Rocky Mountains, from Newberry, and the courses of what have been called *terminal* moraines—which, for the most part, are far from corresponding with the most southern Glacier limit, and therefore are as far from the southern line along which *true terminal* moraines might be looked for.

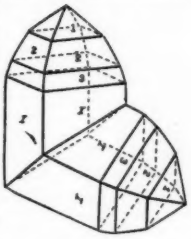
As to artistic merit, the chart has little—greatly disappointing expectation. The colors have been selected and grouped without system or judgment, and are put on not by the chromo-lithographic process, but coarsely by hand, and the effect is both unpleasing and confusing. Where the sheets (of which the chart is made up) join, an area on one is sometimes cut short off instead of having a continuation of the color on the other. Still the chart will be of much service to geologists and in the geological lecture room.

3. *Report on the Geology of Southern New Brunswick*, 1878–1879; by Professors L. W. Bailey, G. I. Matthew and R. W. Ells. Geological Survey of Canada. 26 pp. 8vo. Montreal, 1880. (Dawson Brothers).—This report contains the results of geological observations in the counties Charlotte, Sunbury, Queens, Kings, St. John and Albert. It is accompanied by a geological map of Southern New Brunswick in three parts which out of the four are issued. The map is printed handsomely and effectively in colors, and shows excellent progress by the geologists of the State in their work. There is also a large sheet of geological sections, but with too many doubtful points among them to be in all cases easily understood or satisfactorily interpreted. Careful observations of the strike and dip at each and every outcrop of the rocks, crystalline and uncrystalline, over the whole region, are needed for conclusions as to the stratigraphy.

4. *Text Book of Systematic Mineralogy;* by Henry Bauermann, F.G.S. 367 pp. 12mo. London, 1881, (Longmans, Green and Co.)—This text-book is devoted to a discussion of the general principles of crystallography, and physical and chemical mineralogy; the descriptive mineralogy is to follow in a compan-

ion volume. In the crystallography the author wisely chooses the system of Miller for full development, while the notations of Weiss, Naumann and Lévy are also explained. The statements which precede on the general relations of the systems as to symmetry, and also the descriptions of the various forms under each system, are given with admirable fullness and clearness, and the figures are also numerous and excellent. The author states that he intentionally omits the subject of practical calculation, but had it been possible to abridge a little at other points so as to have made room for a few pages on this part of the subject the usefulness of the book would have been much increased. The difficult subject of optical mineralogy is presented with unusual success, and this also is true of the other topics under physical as also under chemical mineralogy. This volume cannot fail to be widely useful to mineralogical students.

5. *Geniculated Zircons, from Renfrew, Canada;* by W. E. HIDDEN (communicated, March 18).—Undoubted twins of Zircon have lately been observed by the writer from the new locality of apatite and sphene at Renfrew, Canada. The twinning plane (see figure) is 1–*i*, the same as in cassiterite and rutile. The twin, from which the accompanying figure was drawn, weighed over 35 grams, was remarkably perfect and had well polished planes. The color was deep brown-lake and it was transparent in spots. The twins of zircon heretofore described* have been microscopic, and at best questionable.



6. *Rabenhorst's Kryptogamen-Flora von Deutschland, Oesterreich und der Schweiz;* vol. I, parts 1 and 2; by Dr. G. WINTER. —Although the present work is ostensibly a second edition of Rabenhorst's Kryptogamen-Flora, which first appeared in 1844, it has been enlarged and re-arranged to such an extent that it bears little resemblance to the first edition. The new edition is prepared by Grunow, Hauck, Limpricht, Richter, Winter and others, and from this list of names it will be seen that the scope of the work is considerably greater than that of the first edition, which was written by Rabenhorst alone. The marine algæ, for instance, which were before omitted, are to be described by Hauck, whose residence at Triest has given him an opportunity to explore the interesting coast of the northern Adriatic. The two parts already published include the *Schizomycetes*, *Saccharomycetes*, *Entomophthoreæ* and *Ustilagineæ* by Winter. The whole account, including about 150 pages, begins with an introduction on the morphology and physiology of Fungi, with rather minute directions about collecting and mounting specimens. As in Rabenhorst's "Flora Europæa Algarum Aquæ Dulcis," the description of the species of the different orders is preceded by wood

* See Meyer, ZS. G., Ges., xxx, 11,352; Stapff, l. c., xxx, 133, xxxi, 405; Hussak, Min. Petr. Mitth., i, 277, 1878.

cuts illustrating the genera. Under the *Schizomycetes* the cuts are taken principally from Cohn, Koch and Warming, and they are very well executed. The descriptions given by Winter are also excellent, neither uncomfortably condensed nor too diffuse. From the nature of the subject the descriptions of the species should necessarily be followed by notes on the development and variations, and the editor has given much desirable information on the *Schizomycetes*, principally from the works of Cohn and Warming, and in the *Ustilagineæ* the notes are enriched by numerous original observations. W. G. F.

7. *Notes Algologiques, deuxième fascicule;* by Ed. Bornet and G. Thuret.—The second part of the "Notes Algologiques," including 25 quarto lithographic plates and the index to parts one and two, is quite equal to the portion already issued in the clearness of the text and beauty of the plates, which are only surpassed by those of the "Etudes Phycologiques" of the same authors. The second fasciculus differs from the first in that comparatively more attention is paid to the systematic study of the species described, whereas the first fasciculus was devoted mainly to the development of the species. The bulk of the present volume is devoted to the species of *Phycochromaceæ*, especially to the genera *Nostoc* and *Scytonema*, which are given with great minuteness. The portion on *Nostoc* is really a monograph of that genus. Twenty-nine species are recognized and a very large number of synonyms are included under them. To illustrate, *N. commune* Vaucher, as it is commonly called, is referred to the older *N. cinoflonum* Tournefort, and under that name Bornet and Thuret include no less than 32 synonyms. Under *Scytonema* 21 species are recognized, and *S. Ravenelii* Wood has included under it as synonyms *Symphyosiphon Wollei* Bornet, published by Wolle in the Torrey Bulletin, 1877. The American reader will be interested in the account of the species of *Calothrix* and *Isactis*, most of the species figured being common on the American coast. Under *Hormactis Balani*, reference is made to the only species found in the United States, which was at first supposed to be new and was provisionally named *H. Farlowii*. It was afterwards recognized by Dr. Bornet as identical with *Nostoc Quoyi* Ag., of the Marianne Islands, which according to Bornet, is a true *Hormactis*. *H. Quoyi* is known only from the locality named in the Pacific and from the coast of New England, an unusual range for one of the *Phycochromaceæ*. W. G. F.

8. *On the Zoological affinities of Halysites;* by A. E. Verrill.—Of the so-called "tabulate corals" many genera have already had their zoological positions determined. Thus, Agassiz, in 1847, ascertained the hydroid nature of Millepora, and his observations have been fully confirmed by Mosely and others. That Pocillipora and its allies, living and extinct, are true madreporarian corals was shown by me in 1867. That Favosites and the related extinct genera are closely allied to the modern Alveopora and Porites was also demonstrated by me in 1872.*

* This Journal, iii, 187–194.

Mosely, while on the Challenger Expedition, was fortunate in examining the animal of Heliopora. He proved that it belongs to the Alcyonaria, and referred to the same group various fossil genera, in some cases apparently without sufficient reason.

The affinities of the genus *Halysites*, the common "chain coral" of the Silurian, have hitherto been very doubtful. Within a few days Mr. H. T. Woodman has shown me a very remarkable specimen of this genus, in which the internal structure is beautifully preserved. In this example, which is a fragment several inches across, the large tubes contain twelve well-developed and regular septa extending to the center. Their edges are slightly serrulate, and do not rise above the tubes. In other words, the structure is that of a true madreporarian coral.

Mr. Woodman informs me that this specimen is a fragment from a large mass eight to ten feet across, and that "the larger part of the mass was like the common specimens, showing no rays; but here and there, in spots, all over the face of the mass, the septa were as well preserved as in the fragment shown to you."

III. Miscellaneous Scientific Intelligence.

1. *Elements of Comet* (α), 1881, *Swift.*—The elements and the ephemeris for May of comet (α), 1881, Swift, have been calculated by Mr. S. C. Chandler, Jr., at Boston, and by Dr. R. Copeland and Mr. J. G. Lohse at the Dun Echt Observatory in Scotland. These results have been exchanged across the ocean by cable, according to a code adopted by the Boston Scientific Society; they are published in Special Circulars No. 11 and No. 12 of the Science Observer. Mr. Chandler remarked that the comet was (May 7th) a faint round disc less than 1′ in diameter, with some central condensation and ill-defined edges. The orbit does not resemble that of any known comet. The elements are as follows: 1 those of Chandler, 2 those of Copeland and Lohse.

1.

Per. Passage, 1881, May 20·164 Washington Mean Time.
Long. Perihelion, 289° 21′·5
Long. Node, 108 44·1 } Eq. 1881·0
Inclination, 85 29·0
Log. q, 9·74330
Motion direct.

2.

Per. Passage, 1881, May 20·67, Greenwich Mean Time.
Long. Perihelion, 300° 5′
Long. Node, 124 54 } Eq. 1881·0.
$\omega = \pi - \Omega$, 175 8
Inclination, 78 48
Log. $q = 9{\cdot}7674$ $q = 5854$.
Motion direct.

2. *National Academy of Sciences.*—The following is a list of the papers read at the session of the National Academy of Sciences at Washington, in April:

A. GRAHAM BELL: Upon the production of sound by radiant energy.

S. P. LANGLEY: The solar constant; The color of the sun; On mountain observations.

C. S. PEIRCE: On the progress of pendulum work.

GEO. F. BARKER: On electric light photometry; On incandescent lights; On the condenser method of measuring high tension currents; On the carbon lamp fiber in the thermo balance.

EDW. S. MORSE: On the utilization of the sun's rays in heating and ventilating.

J. W. MALLET: Results just obtained with regard to the molecular weight of hydro-fluoric acid.

C. H. F. PETERS: A method for finding the proximities of the orbits of minor planets.

ELIAS LOOMIS: Reduction to sea-level of barometric observations made at elevated stations.

W. H. DALL: Recent researches in the vicinity of Behring's Strait, comprising: I. An account of the land-ice of Kotzebue Sound and the Arctic Coast. II. Additions to our knowledge of the currents and temperature of the ocean in the vicinity of Behring's Strait.

E. W. HILGARD: On the later Tertiary of the Gulf of Mexico.

T. STERRY HUNT: On the auriferous gravels of California; On the domain of physiology.

B. ALVORD: The compass plant of the Western prairie.

E. D. COPE: On the relation between strains and impacts and the structures of the feet of mammalia.

R. PUMPELLY: On the relation of soils to health.

J. P. LESLEY: Biographical memoir of S. S. Haldeman.

3. *Popular Lectures on Scientific Subjects;* by H. HELMHOLTZ, translated by E. Atkinson. Second series. 265 pp. 8vo. New York (D. Appleton and Co.).—The subjects of these lectures, for the general interest of which the author's previous publications are a sufficient guarantee, are: 1, Gustav Magnus; 2, Origin and significance of geometrical atoms; 3, Relation of optics to painting; 4, Origin of the planetary system; 5, Thought in medicine; 6, Academic freedom in German universities.

4. *The Constants of Nature, Part IV; Atomic weight determinations; a digest of the investigations published since* 1814; by GEORGE F. BECKER. 149 pp. 8vo. Washington, 1880, (Smithsonian Miscellaneous Collections).—Mr. Becker has brought together in small compass a large amount of material, which cannot fail to be of much practical value to the working chemist. The abstracts are necessarily very brief, but when more is needed reference can be readily made to the original papers, the abstract being at least sufficient to show what may be expected in them.

Observations of the Transit of Venus, Dec. 8–9, 1874, made and reduced under the direction of the Commission created by Congress. Edited by Simon Newcomb, U. S. Navy, Secretary of the Commission. 157 pp., 4to, with two plates. Washington, 1881.

The Total Solar Eclipse of July 29, 1878. Observations at Pike's Peak, Colorado. Report by Professor S. P. Langley. pp. 203–217, with a plate.

Observations on Jupiter, by L. Trouvelot; pp. 299–321, from the Proceedings of the American Academy of Arts and Sciences, vol. xvi.

Mittheilungen aus der Zoologischen Station zu Neapel, zugleich ein Repertorium für Mittelmeerkunde, vol. ii, II, III, pp. 123–413.

Working Drawings: How to make and use them; by L. M. Haupt. 55 pp. 12mo, with 30 figures. Philadelphia, 1881. (J. M. Stoddart & Co.)

APPENDIX.

ART. LXII.—*Notice of new Jurassic Mammals;* by Professor O. C. MARSH.

AMONG the fossils from the Atlantosaurus beds of the Rocky Mountains recently received at the Yale College Museum, are the remains of several mammals distinct from those hitherto described by the writer.* These include two new genera, and four species, which are described below. This material throws much light on the specimens previously discovered, and also shows some peculiar characters not before seen in mammals.

Allodon laticeps, gen. et sp. nov.

The type specimen of the present species is a left upper jaw, with molar and premolar teeth in good preservation. This specimen indicates that the skull was a short and broad one. The anterior half of the zygoma is in place, and shows that the arch was strong, and widely expanded. There are five premolars, and two molars in position, and in front of this series is a single alveolus which was occupied by a small premolar, or perhaps by a weak canine. The premolars have each two fangs, and tuberculated crowns, which are nearly flat on the inner side, and rounded externally. The two true molars strongly resemble those of *Microlestes*, and hence are similar in form to the lower molars of *Plagiaulax* and *Ctenacodon*. The crowns are very low, and are divided into an outer and an inner half by a deep worn groove. The last molar has its longitudinal groove in a line with the inner margin of the other teeth. The principal measurements of this specimen are as follows:

Space occupied by seven posterior teeth	8·mm
Extent of two true molars	2·5
Distance from orbit to margin of upper jaw	2·
Extent of maxillary above second premolar	2·

* This Journal, vol. xv, p. 459, vol. xviii, pp. 60, 215 and 396, and vol. xx, p. 235.

The affinities of this peculiar species are not easy to determine, but it should probably be placed in the *Plagiaulacidæ*. The number of premolars shows that it is distinct from the known genera of this group.

The only specimen known indicates an animal about as large as a weasel. It was found in the Upper Jurassic deposits of Wyoming.

Ctenacodon nanus, sp. nov.

A second and smaller species of this genus is indicated by two lower jaws, found separately. One of these, the type specimen, has the four premolars and two molars in place, and well preserved. The former teeth all have two fangs, and smooth, sharp compressed crowns. The last premolar only has its summit marked by faint notches. The molars have one cone with a broad base on the outer side, and three low inner cones of nearly equal size. Between these is a deep worn longitudinal valley, as in the molars of *Allodon*, above described. There is no cingulum, and the two molars are of the same size. The coronoid process rises immediately behind the last molar. The ridge starting at the base of the coronoid and extending forward on the outer side is much sharper than in the larger species (*Ctenacodon serratus*).

The following measurements will indicate the size of this specimen:

Extent of premolar and molar series	6·mm
Extent of premolar series	4·
Antero-posterior diameter of last premolar	1·5
Height of crown	1·25
Height of condyle	2·5
Width of condyle	1·5

The specimens representing the present species are from the Atlantosaurus beds of Wyoming.

Docodon striatus, gen. et sp. nov.

The present genus is most nearly allied to *Diplocynodon*, but may be distinguished from it by having, in the lower jaw behind the canine, eleven teeth instead of twelve. The canine has two fangs, as in that genus, and the molar teeth also correspond closely in form. In the present species, the lower jaws are long and comparatively slender. The symphysis is very long, and the mylohyoid groove extends forward to its upper border. The inner side of the lower jaw is distinctly striate. The condyle is wider than in *Diplocynodon victor*.

Some of the dimensions of the type specimen are as follows:

Distance from apex of canine to end of condyle	31·mm
Extent of premolar and molar series	17·
Depth of lower jaw below last molar	4·
Depth of lower jaw below canine	3·
Height of crown of canine	2·5

The only known remains of the present species are from the Upper Jurassic deposits in Wyoming.

Dryolestes gracilis, sp. nov.

The present species, which is the smallest of the genus, is represented by several lower jaws, which are unusually long and slender, and nearly straight. In the type specimen, there were eleven teeth behind the canine, which was of moderate size. The fangs of the molar teeth are not placed one in front of the other, but opposite, with one large fang on the outside, and a small inner one beside it. This peculiar feature appears in all the species of *Dryolestes*, but has not been observed in any other mammals, recent or extinct. The mylohyoid groove in this specimen is deep, and extends forward, nearly parallel with the lower border, to the symphysis. The following measurements show the size of the best preserved lower jaw referred to the present species:

Extent of eleven posterior teeth	11·mm
Extent of last five teeth	6·
Depth of jaw below canine	1·
Depth of jaw below last molar	2·

All the known specimens of this species are from the Upper Jurassic deposits of Wyoming Territory.

Yale College, New Haven, May 24th, 1881.

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